NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

CONVENTIONAL AND PROBABILISTIC FATIGUE LIFE PREDICTION METHODOLOGIES RELEVANT TO THE P-3C AIRCRAFT

by

Todd R. Kousky

March, 1997

Thesis Advisor: Edward M. Wu

Approved for public release; distribution is unlimited.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 1997	Master's Thesis

TITLE AND SUBTITLE CONVENTIONAL AND PROBABILISTIC FATIGUE LIFE PREDICTION METHODOLOGIES RELEVANT TO THE P-3C AIRCRAFT

5. FUNDING NUMBERS N0001996WXCD3YA

6. AUTHOR(S)
Kousky, Todd R.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Naval Air Systems Command (PMA-290FA/JP1)
Attn: CDR Jeffrey Kunkel
1421 Jefferson Davis Hwy.
Arlington, Virginia 22243-2900

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release; distribution unlimited.	

13. ABSTRACT *(maximum 200 words)*

This thesis investigates conventional and probabilistic methodologies for predicting the fatigue life of critical components in the P-3C aircraft. A probabilistic damage convolution model was developed with the intent of providing quantitative predictions of life-variability. Traditional methodologies, which are based nominally on median values, lack the capacity to adequately assess variability. Aluminum 7075-T6 was tested using a fatigue Material Test System. A fatigue data base was compiled from tests conducted at the Naval Postgraduate School and from literature sources.

14. SUBJECT TERMS
P-3C Aircraft, Fatigue Life Prediction, Aluminum 7075-T6, Fatigue Data Base, Probability, Reliability

15. NUMBER OF PAGES 159

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFI- CATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

Approved for public release; distribution is unlimited

CONVENTIONAL AND PROBABILISTIC FATIGUE LIFE PREDICTION METHODOLOGIES RELEVANT TO THE P-3C AIRCRAFT

Todd R. Kousky
Lieutenant, United States Navy
B.S., United States Naval Academy, 1989

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
March 1997

Author: Todd R Kousky
Todd R. Kousky

Approved by: Edward M. Wu
Edward M. Wu, Thesis Advisor

G H Lindsey
Gerald H. Lindsey, Second Reader

Daniel J. Collins
Daniel J. Collins, Chairman
Department of Aeronautics and Astronautics

ABSTRACT

This thesis investigates conventional and probabilistic methodologies for predicting the fatigue life of critical components in the P-3C aircraft. A probabilistic damage convolution model was developed with the intent of providing quantitative predictions of life-variability. Traditional methodologies, which are based nominally on median values, lack the capacity to adequately assess variability. Aluminum 7075-T6 was tested using a fatigue Material Test System. A fatigue data base was compiled from tests conducted at the Naval Postgraduate School and from literature sources.

TABLE OF CONTENTS

ACKNOWLEDGEMENT

The author would like to acknowledge the financial support of NAVAIR (PMA-290) for allowing the purchase of equipment used in this thesis. This work was performed under contract N0001996WXCD3YA. The author wants to thank Professor Edward M. Wu for his professional commitment to education and the advancement of science, as well as his dedication to the fleet. His advice and work on this thesis was indispensable and made this a valuable learning experience. The author also wants to thank Professor Gerald H. Lindsey for his support and help in editing this work.

Special thanks to my wife, Jenny, and children, Chad and Paul. Their faithful support and understanding inspired me.

I. INTRODUCTION

A. BACKGROUND AND PERSPECTIVE

The Navy's maritime patrol aircraft, P-3 Orion, is expected to be in service until the year 2015. Until that time no funding for a replacement aircraft is envisioned. However, a life extension program is being formulated and funded to assure the safety of the air crew and availability of aircraft for necessary missions. Several programs under the Naval Aircraft Structural Integrity Program (NASIP) that apply to the P-3 are diagrammed in Figure 1.1. As part of the Aircraft Structural Life Surveillance (ASLS) Program, the Structural Appraisal of Fatigue Effects (SAFE) monitors the life of the existing fleet P-3's. The Sustained Readiness Program (SRP) is established to ensure that these P-3's at least reach their current certification life. Furthermore, the Structural Life Assessment Program (SLAP) is required by law to justify life extension. Finally, the Service Life Extension Program (SLEP) is being formulated with the goal of extending the certification life.

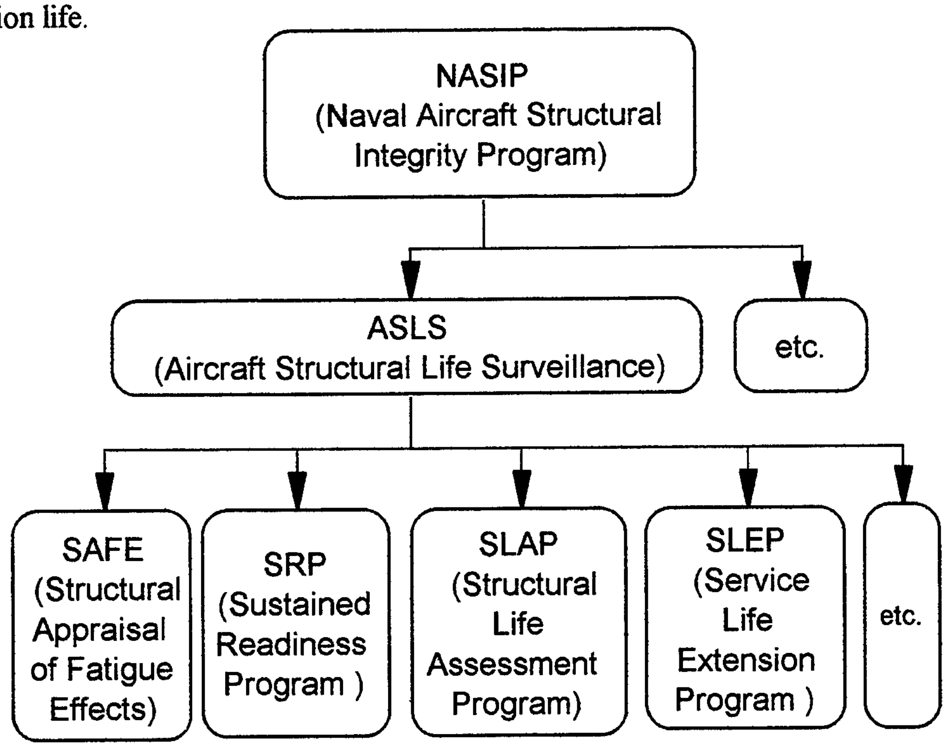


Figure 1.1 P-3 NASIP Outline

Historically, the P-3 airframe has been fatigue tested to 10,000 hours during the original design phase. The current certification life of 24,000 flight hours has evolved from analytical predictions. Since some of the Lockheed Electra's (civilian version of P-3) are still operating at flight hours well beyond 24,000, the Navy is hopeful of extending the life of the P-3. Currently Lockheed is under contract to develop testing strategies for the Service Life Extension Program (SLEP). In fiscal year 1999, a contract will be awarded for a destructive full-scale article fatigue test on a 25 year-old P-3.

The Sustained Readiness Program (SRP) is initiated to battle corrosion. Many aircraft will not reach their certification life if corrosion problems are not addressed and eradicated. In the past, corrosion had been buffed out without a good record of how much structural material was removed and from which specific areas. SRP identifies the corroded aircraft components, which are then replaced with new material vice eradication of corrosion via buffing. In effect, this process creates a "like new condition". Based on material type, severity of corrosion and potential for fatigue damage, some removed parts are placed into Sustained Readiness Program (SRP) "core kits" for use in research (e.g., Core Kit W1-Wing Front Spar; Web and Caps).

Structural Appraisal of Fatigue Effects (SAFE) determines and tracks the fatigue life expended (FLE) for each P-3 aircraft. FLE per aircraft is tracked via 30 critical components or "hot spots" which have been identified by several Lockheed tests. An indicated FLE of 100 % is expected to ensure a 99% likelihood of a crack-free structure. AeroStructures, Inc. uses the Fatigue Analysis of Metallic Structures (FAMS) computer program to calculate FLE for each of the 30 critical structural locations. FAMS uses an input of the flight load spectrum of each aircraft. The resulting SAFE reports, which are published quarterly, identify hot spot No. 12 (Wing Station 209, lower front spar web) as the leading area of FLE for most P-3 aircraft.

The overall objective of these P-3 structural integrity programs is to provide increased reliability against failure during the service lifetime. Since fatigue testing, which is time consuming and destructive, cannot be conducted on a large scale, the

existing methodology is based on the statistics of limited samples. Many assumptions of uncertain validity are required to utilize such statistical data. A probabilistic approach originated by B. Coleman [Ref. 1] utilizes a convolution integral to assess damage resulting from different load histories. The Naval Postgraduate School (NPS) can contribute to the life extension program through the evaluation of conventional methodology and the formulation of modern damage accumulation to supplement the conventional fatigue analysis, from constant amplitude load history to spectrum load history, and to extend the prediction to include life variability.

B. NPS P-3 LIFE EXTENSION PROGRAM

The strategy of the NPS participation is to develop fatigue data for the aluminum alloy used in P-3 structures. A data generation program will be kept productive by overlapping thesis students. Additional data will be compiled from literature and laboratory sources. The data will be interpreted by conventional fatigue analysis, and variability predictions will be explored as appropriate.

In the near term, data collection is underway for constant amplitude fatigue tests and the equipment for spectrum fatigue testing is being assembled for the second phase of testing. Spectrum fatigue data, when available, will be interpreted by damage convolution. The result will be compared to constant amplitude fatigue prediction such that a methodology for spectrum life prediction is available for modified flight profiles. These verifications will be performed on new samples, which will be subjected to a variable amplitude load history in the laboratory.

In the intermediate term, structural parts (from "core-kits") with known service histories will be made into laboratory samples. Additional spectrum fatigue loading will be applied until failure. The observed residual life will be compared to the predicted residual life using the damage function convolution method, as well as conventional methods.

In the long term, critical sub-structural components (with known service history), such as a wing box, will be tested in the actual structural configuration. Structural fatigue damage, when observed in the laboratory test, will be refurbished and testing will be continued. This will allow a lead time to forewarn of any needed refurbishment of fleet aircraft. Figure 1.2 outlines the proposed P-3 life extension program at NPS.

C. SCOPE OF THIS RESEARCH

The scope of this research was to explore methods for predicting the fatigue life of critical components in the P-3 aircraft and to generate a related fatigue database. Conventional and probabilistic fatigue life prediction methodologies were examined in parallel. As reported in the open literature for over 35 years, conventional fatigue life prediction methods, based on statistics, suffer due to a lack of sufficient data for statistical qualification. For this reason, median values are traditionally applied to lifetimes. Statistics are usually not adequate for predicting life variability because economic considerations make it impractical to run the large number of fatigue tests required.

Metal fatigue can exhibit wide scatter in fatigue testing data, which implies a very large variation in lifetime. Probabilistic methods, which have not been widely applied to fatigue, predict the life variability based on the underlying physical phenomena and a statistical inference. Both conventional and probabilistic fatigue life prediction methodologies use the same set of data.

Fatigue data for Aluminum 7075-T6 was compiled for this thesis. Aluminum 7075-T6 is the primary material of the critical components in the P-3. Emphasis was placed on sheet stock, as sheet material is used in the primary hot spot (Wing Station 209, lower front spar web). Testing materials and equipment were assembled, and constant amplitude data was produced from tests conducted at NPS. Additional fatigue data was compiled from literature and laboratory sources.

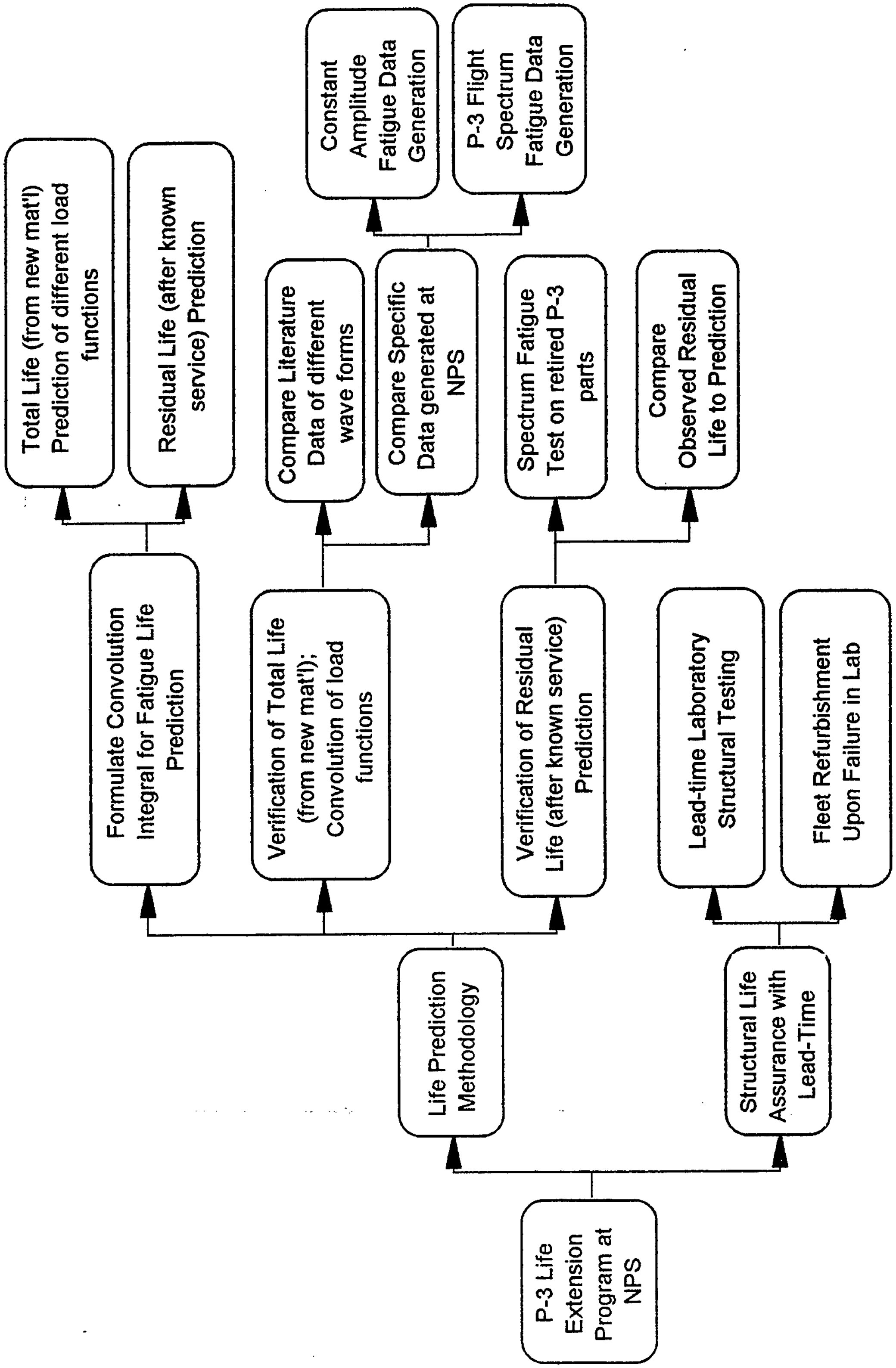


Figure 1.2 Proposed P-3 Life Extension Program at NPS

II. CONVENTIONAL FATIGUE LIFE PREDICTION

Fatigue damage during the crack initiation phase can be related to dislocation movements and similar mechanisms which occur on a microscopic level. Due to the difficulty in measuring such phenomena, most cumulative damage methods are empirical. In the case of the Palmgren-Miner hypothesis, the energy loss due to hysteresis loops of different magnitudes is considered additive. Based on this idea, a linear damage method called Miner's rule follows:

$$\sum \frac{n_i}{N_i} \geq 1 \tag{2.1}$$

Where n_i is the number of cycles at a given stress level S_i and N_i is the fatigue life in cycles at this stress level. Failure is assumed to occur when the summation of damage fractions is ≥ 1. When the ability of the material to dissipate energy from hysteresis loops reaches a limit, crack initiation occurs. However, Miner's linear damage rule does not account for sequence effects, such as the mean stress effect, which is caused by residual stress.

The rainflow counting approach originally presented by Matsuishi and Endo presents an analogy where the strain history forms a series of pagoda roofs. Hysteresis cycles are defined based on how the rain flows off these roofs, as illustrated in Figure 2.1:

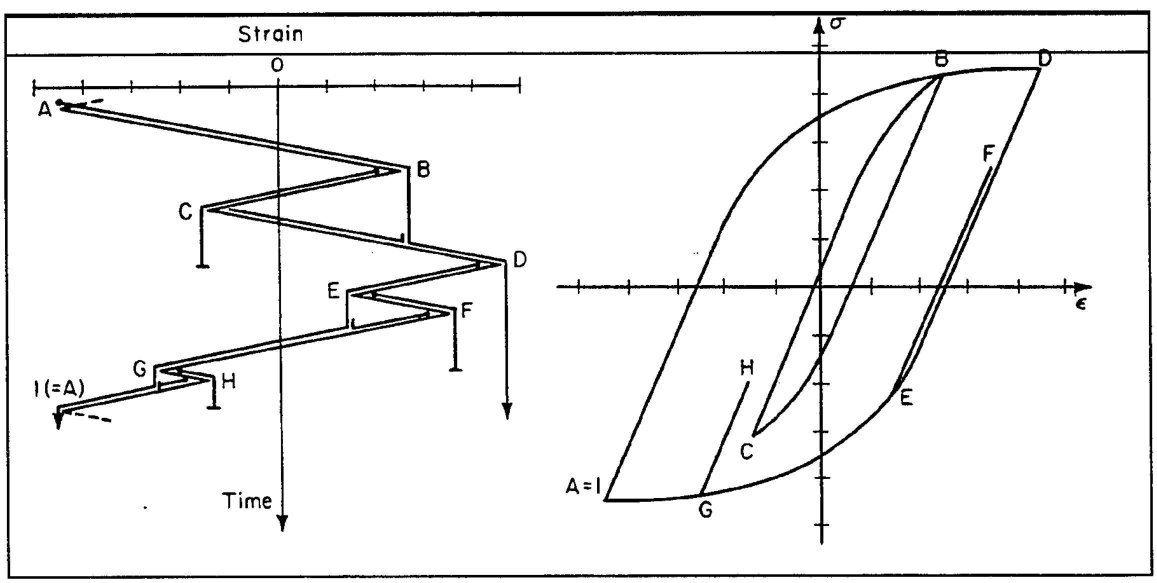


Figure 2.1 Stress-strain response to given strain history [Ref. 2:p.192].

In Figure 2.1, four events occur as closed hysteresis loops, each having its own strain range and mean stress value. The damage of each hysteresis cycle is accumulated using Miner's rule. The sequence effect, whereby mean stress influences fatigue damage, is accounted for, because each rainflow-counted strain cycle occurs about its appropriate mean stress.

Physically, the rainflow count reduces the stress-strain history to hysteresis loops which include mean stress effects. Several methods employ the rainflow count to convert a variable load history to linear damage. Three examples using strain-life equations that include mean stress effects follow:

Morrow: $$\frac{\Delta\varepsilon}{2} = \frac{\sigma_f' - \sigma_m}{E}(2N_f)^b + \varepsilon_f'(2N_f)^c \qquad (2.2)$$

Manson-Halford: $$\frac{\Delta\varepsilon}{2} = \frac{\sigma_f' - \sigma_m}{E}(2N_f)^b + \varepsilon_f'\left(\frac{\sigma_f' - \sigma_m}{\sigma_f'}\right)^{\frac{c}{b}}(2N_f)^c \qquad (2.3)$$

Smith-Watson-Topper: $$\sigma_{max}\frac{\Delta\varepsilon}{2} = \frac{(\sigma_f')^b}{E}(2N_f)^{2b} + \sigma_f'\varepsilon_f'(2N_f)^{b+c}$$

(2.4)

where $$\sigma_{max} = \frac{\Delta\sigma}{2} + \sigma_m \qquad (2.5)$$

These equations can be solved for the life to failure, N_f, given the value of the mean stress, σ_m, strain range, $\Delta\varepsilon$, and /or the stress range, $\Delta\sigma$, for a hysteresis loop. Consequently, $1/N_f$ corresponds to Miner's damage fraction for the hysteresis loop. Again, life to failure will be predicted when the cumulative damage from individual hysteresis loops is ≥ 1.

At the Naval Postgraduate School, the Fatigue Life Program (FLP) was developed by LT Michael Skelly [Ref. 3]. FLP calculates the cycles to failure using a choice of strain-life equation; either Morrow's, Manson-Halford, or Smith-Watson-Topper. The computer program reads in a specified load sequence using stress or strain as an input.

A similar computer program called the Fatigue Analysis of Metallic Structures (FAMS) used by AeroStructures, Inc. (ASI) also utilizes the rainflow count method. However, instead of using a strain-life equation that incorporates mean stress, as above, the mean strains of each hysteresis loop are converted to an equivalent strain at zero mean stress. Then, by entering the strain-life curve for completely reversed straining about zero mean load with the equivalent strain, the life N_f is determined.

FAMS uses Morrow's linear relationship, Eq. 2.6, to convert the actual hysteresis loop strain amplitude, ε_a, to an equivalent strain amplitude at zero mean, ε_{eq}.

$$\frac{\varepsilon_a}{\varepsilon_{eq}} + \frac{\sigma_m}{\sigma_f} = 1 \qquad (2.6)$$

This relationship is shown graphically in Figure 2.2:

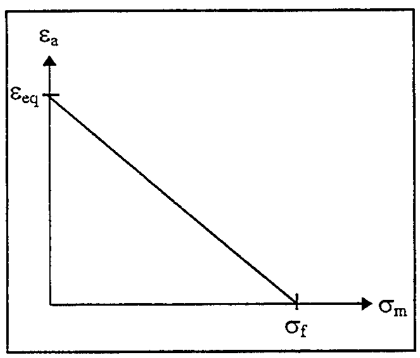


Figure 2.2 Morrow's linear relationship.

Once ε_{eq} has been determined, the strain-life curve for zero mean can be used to find N_f.

Figure 2.3 depicts the strain-life curve where the total strain amplitude has been resolved into elastic and plastic strain components from steady-state hysteresis loops. At a given life, N_f, the total strain is the sum of the elastic and plastic strains. Both the elastic and plastic curves can be approximated as straight lines. At large strains or short lives, the plastic strain component dominates, and at small strains or longer lives, the elastic strain component dominates.

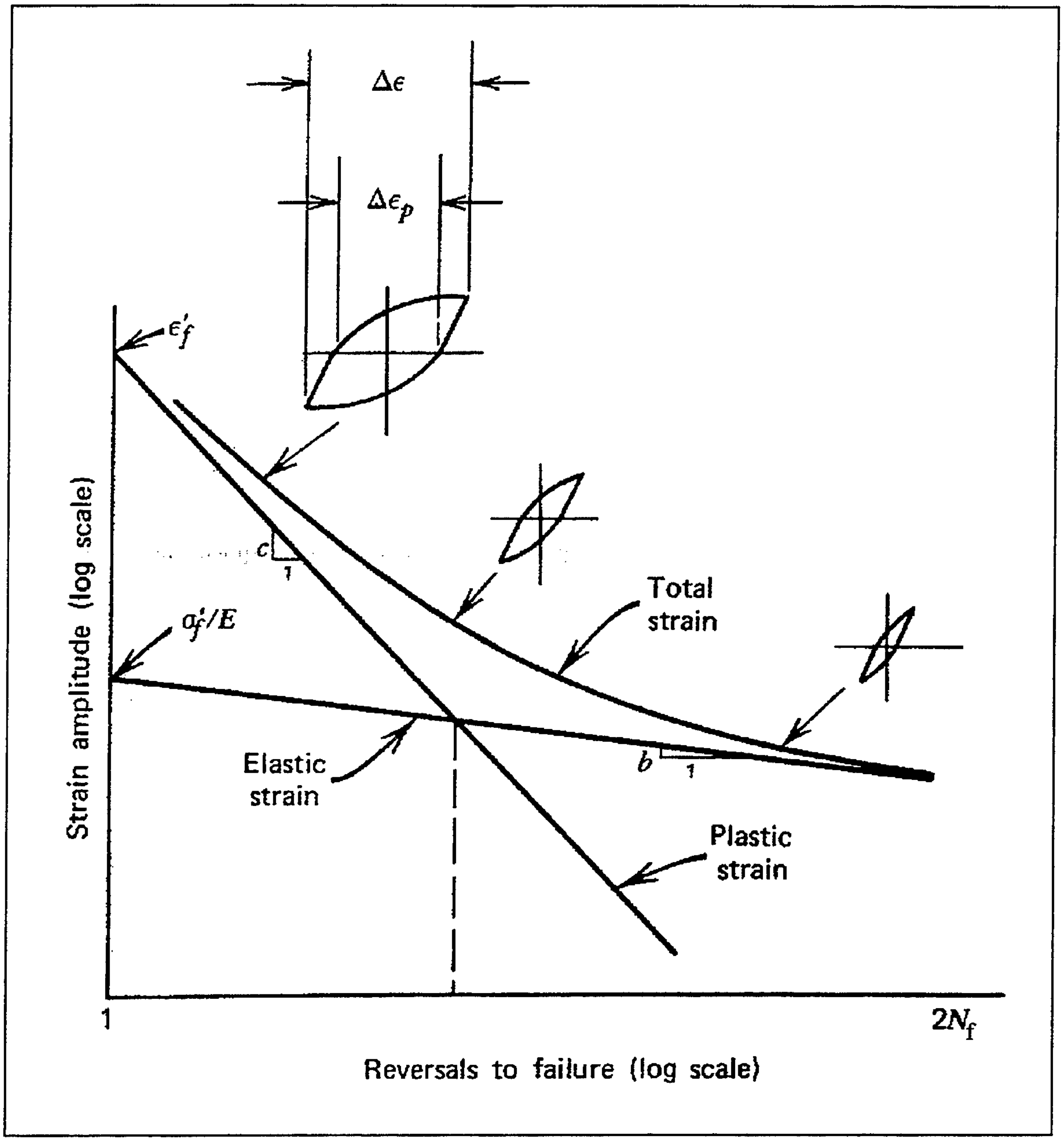


Figure 2.3 Strain-life curve showing total, elastic, and plastic strain components. [Ref. 4:p. 77]

The strain-life curve for zero mean strain is described by the following strain-life equation:

$$\frac{\Delta\varepsilon}{2} = \frac{\sigma_f'}{E}(2N_f)^b + \varepsilon_f'(2N_f)^c \tag{2.7}$$

where $\Delta\varepsilon/2$ is the total strain amplitude or in the case of FAMS methodology, $\Delta\varepsilon/2$ is ε_{eq}.

The elastic strain amplitude, $\Delta\varepsilon_e/2$, and plastic strain amplitude, $\Delta\varepsilon_p/2$, are shown in Eq. 2.8 and Eq. 2.9, respectively:

$$\frac{\Delta\varepsilon_e}{2} = \frac{\sigma_f'}{E}\left(2N_f\right)^b \tag{2.8}$$

$$\frac{\Delta\varepsilon_p}{2} = \varepsilon_f'\left(2N_f\right)^c \tag{2.9}$$

Note that a distinction exists between strain-life and stress-life methodologies. At long lives, where plastic strain is negligible, and stress and strain are easily related, the strain-life and stress-life approaches are essentially the same. The load levels are low, so stresses and strains are linearly related. Therefore, in this range load-controlled and strain-controlled test results are equivalent. However, for low cycle fatigue, where damage depends on plastic deformation, the strain-life approach is required. In the plastic region, strain-control is used for fatigue testing to provide the high resolution needed because stress and strain are non-linearly related.

Strain-life methods are considered crack-initiation life estimates and are employed by the U. S. Navy. In the case of the U. S. Air Force, crack initiation is considered an overly conservative criterion for component failure. Therefore, the Air Force uses fracture mechanics methods to determine crack propagation life from an assumed initial crack size to a final critical crack length. The fracture mechanics approach, which requires more extensive inspections, is generally not considered suitable for Naval operations.

III. PROBABILISTIC APPROACH TO FATIGUE

A. INTRODUCTION

The conventional fatigue-life prediction methodology, which relies on experience based weighting factors known as safety factors and safety margins, gives little indication of the failure probability of the component. Failure probability may vary from low to very high for the same safety factor. Much of the conventional statistical methodology is not applicable to analysis of the reliability of an aircraft against failure by fatigue. Use of the "mean time between failures" is not acceptable when the real concern is the time of the first failure.

Probabilistic methodology, on the other hand, is adequate for calculating component reliability. Probability can be applied to obtain a quantitative assessment of the variability in fatigue life. Therefore, a probabilistic approach may add real value to current methodologies for predicting reliability and readiness of Naval aircraft. From a reliability perspective, the probability of having one failure of a hot spot on a specific aircraft at a given number of flight hours can be determined. Similarly from a readiness point of view, the number of aircraft, fleet wide, which will need to be reworked to keep the probability of failure below a reliability target can be determined.

Probabilistic methodology identifies explicitly all the variables and parameters which determine both the stress, strength, and life distributions. Figure 3.1 illustrates various factors which contribute to the stress and strength distributions. Once the underlying distributions are determined, the component reliability can be calculated. Although the probabilistic methodology necessary for properly dealing with fatigue problems has been available for some time, it remains largely unapplied.

Modern personal computers are capable of performing reliability calculations and simulations that are impossible by hand. Information theory can now be applied to the development of data and to reliability approaches that had little engineering promise in previous decades.

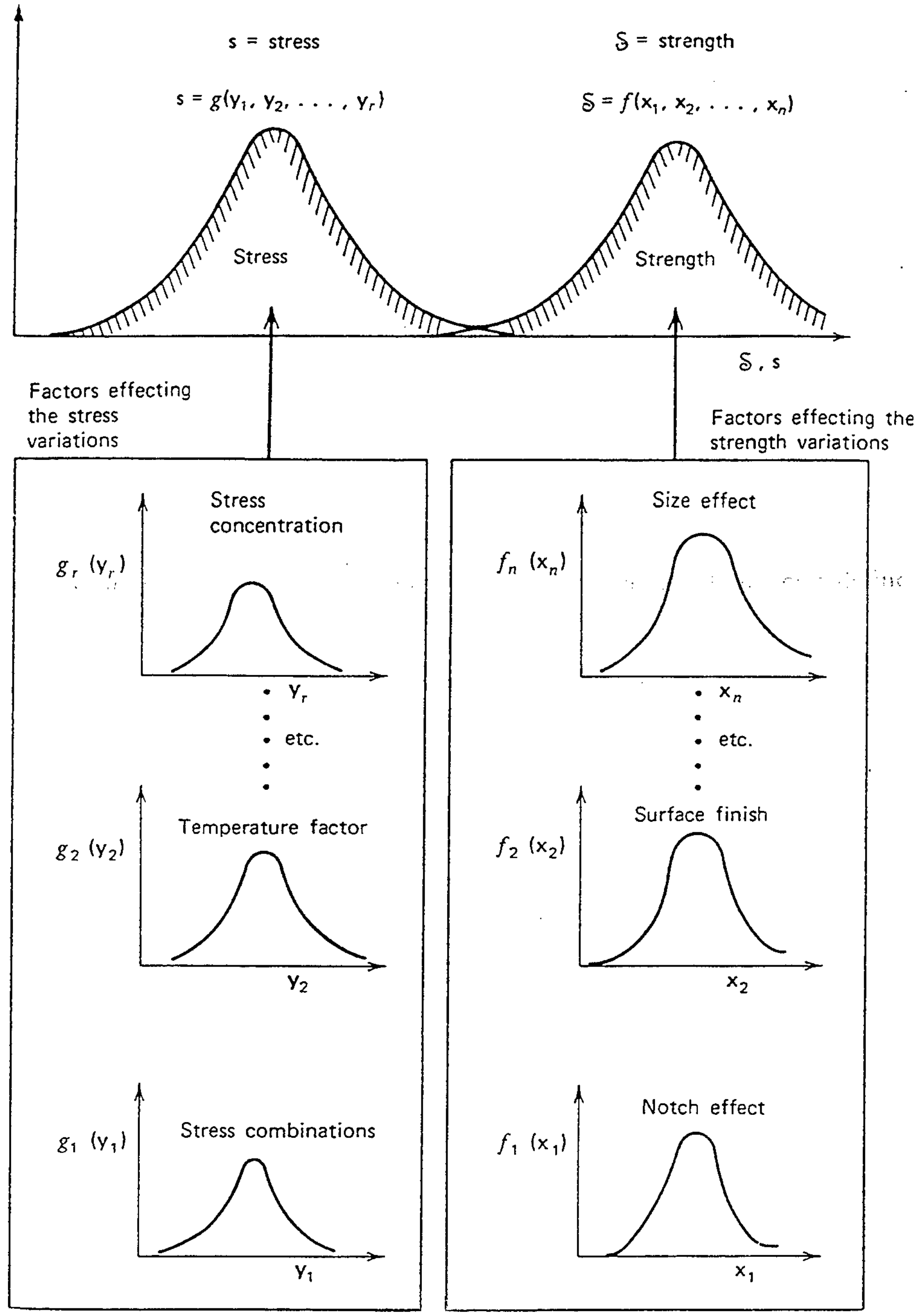


Figure 3.1 An illustration of various factors contributing to the stress and strength distribution. [Ref. 5:p. 74]

The type of information that can be obtained from a probabilistic analysis of S-N (stress-life) data is demonstrated in Figures 3.2 and 3.3. These figures depict a three-dimensional probability distribution function (pdf) and cumulative distribution function (CDF) in which the probability of component failure is given per flight hour and varies with operating stress level. The three-dimensional pdf and CDF, contain reliability and readiness information, respectively, as described previously.

The three-dimensional pdf and CDF plots are more realistic than the conventional S-N curves which do not account for variability. The conventional S-N curve is merely an average of fatigue life distributions and strength distributions as shown in Figures 3.4a, 3.4b, and 3.4c. Note that the S-N curve, and the three-dimensional pdf and CDF plots, represent the same set of fatigue data.

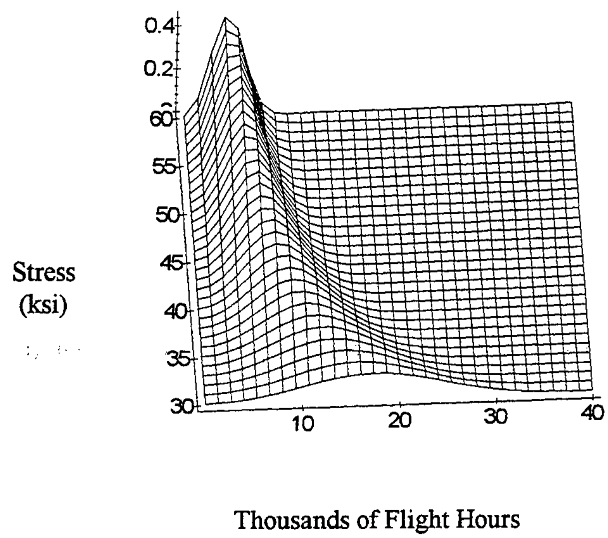


Figure 3.2 3-D probability distribution function (pdf)

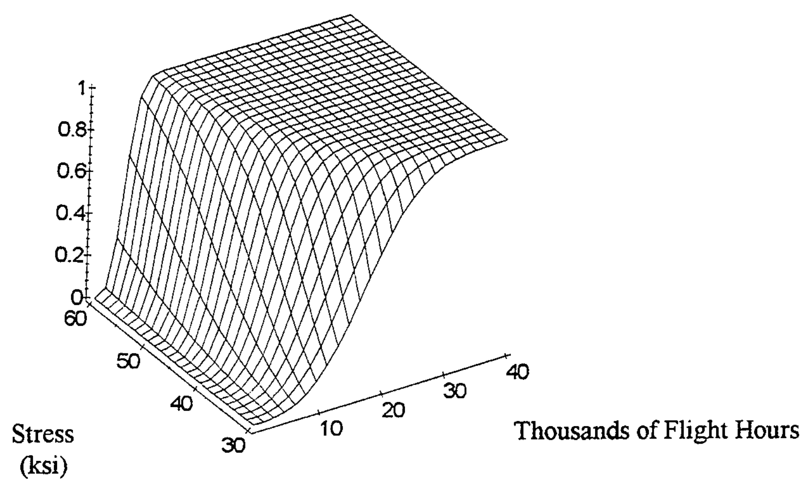


Figure 3.3 3-D Cumulative Distribution Function (CDF)

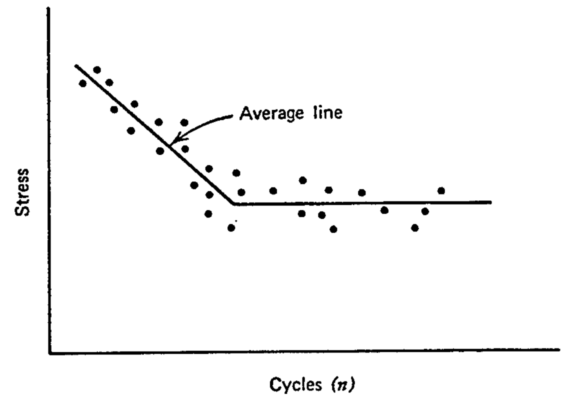


Figure 3.4a Conventional S-N diagram (log-log scale) [Ref. 5:p. 191]

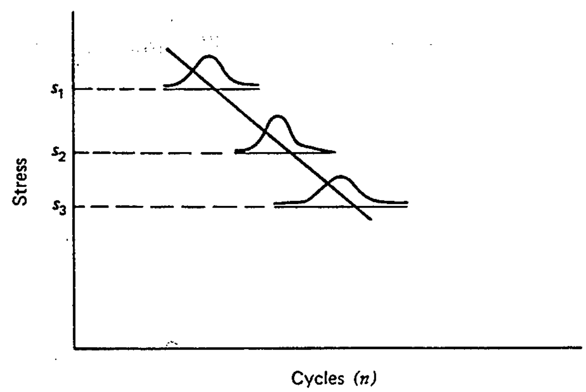


Figure 3.4b Scatter in fatigue life at a given stress (log-log scale) [Ref. 5:p. 191]

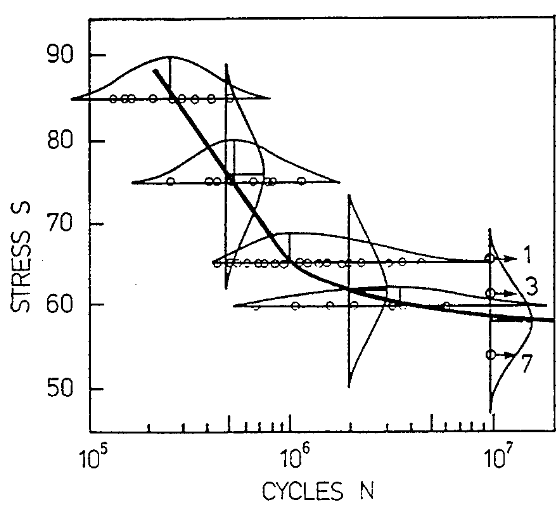


Figure 3.4c Fatigue life distributions and strength distributions [Ref. 6:p. 94]

B. PROBABILITY CONCEPTS

A brief introduction to probability concepts is included to provide a foundation for probabilistic methodologies. Let A and B represent two hot spot locations on a given P-3. Then the occurrence of event A corresponds to a fatigue failure of the critical component at hot spot A.

$P\{A\}$;	The probability event A occurs	(3.1)
$A \cap B$;	Intersection, both event A and B occur	(3.2)
$A \cup B$;	Union, either A or B or both event A and B occur	(3.3)
$P\{A \cap B\} = P\{A\|B\}P\{B\}$;	3rd axiom of probability theory	(3.4)

The conditional probability of event A, given event B is defined as $P\{A|B\}$. Hence, the 3rd axiom of probability theory states that the probability both A and B will occur is just the probability that B occurs times the conditional probability that A occurs, given the occurrence of B (provided that the probability that B occurs is greater than zero). For events to be **independent**, the probability of one occurring cannot depend on the fact that the other is either occurring or not occurring. Thus if A and B are independent,

$$P\{A|B\} = P\{A\} \tag{3.5}$$

and $P\{A \cap B\} = P\{A|B\}P\{B\}$ becomes,

$$P\{A \cap B\} = P\{A\}P\{B\} \tag{3.6}$$

Another situation arises in probability where two events are **mutually exclusive**. That is, if A occurs, then B cannot, and conversely. Thus $P\{A|B\} = 0$ and $P\{B|A\} = 0$, or for mutually exclusive events

$$P\{A \cap B\} = 0 \tag{3.7}$$

The union, $A \cup B$, noted above as either A or B or both event A and B occur, written in terms of probability $P\{A \cup B\}$ follows:

$$P\{A \cup B\} = P\{A\} + P\{B\} - P\{A \cap B\} \tag{3.8}$$

If events A and B are **independent** of one another, then

$$P\{A \cup B\} = P\{A\} + P\{B\} - P\{A\}P\{B\} \tag{3.9}$$

Furthermore, for **mutually exclusive** events

$$P\{A \cup B\} = P\{A\} + P\{B\} \tag{3.10}$$

The concepts shown above for a two component system can be extended by Boolean algebra to a three and four component system as shown below:

$$P\{A\cup B\cup C\} = P\{A\}+P\{B\}+P\{C\}-P\{A\cap B\}-P\{B\cap C\}-P\{A\cap C\}+ P\{A\cap B\cap C\} \quad (3.11)$$

$$P\{A\cap B\cap C\} = P\{A|B\cap C\}P\{B\cap C\} = P\{A|B\cap C\}P\{B|C\}P\{C\} \quad (3.12)$$

$$P\{A\cup B\cup C\cup D\} = P\{A\}+P\{B\}+P\{C\}+P\{D\}-P\{A\cap B\}-P\{B\cap C\}-P\{A\cap C\}- P\{A\cap D\}-P\{B\cap D\}-P\{C\cap D\}+P\{A\cap B\cap C\cap D\} \quad (3.13)$$

$$P\{A\cap B\cap C\cap D\} = P\{A|B\cap C\cap D\}P\{B\cap C\cap D\} = = P\{A|B\cap C\cap D\}P\{B|C\cap D\}P\{C|D\}P\{D\} \quad (3.14)$$

C. WEIBULL DISTRIBUTION

Historically, the normal, log normal, extreme value, and Weibull distributions have been used as *adequate* fatigue failure density models for various metals. In fact, when dealing with probabilities about the mean, all of these models will provide reasonable results. However, when estimating the tail probabilities, it is believed that the Weibull model best matches the underlying physics of fatigue failure.

The Weibull distribution is particularly justified for situations where a "worst link" is responsible for failure. In the case of fatigue failure it is assumed that the fracture starts at the weakest point analogous to the weakest link in a chain. Consider a component comprised of N elements. For the component to have life, τ, each element must have life, τ. If any one element does not have life, τ, the whole component fails. In other words, when the weakest link fails, the component fails.

The weakest link phenomena may be illustrated using Boolean algebra. The reliability of the component is conceptually a chain of elements, or series of links. The fatigue strengths of the N links are described by the random variables $X_1, X_2, X_3 \ldots X_N$. For a three component system where **R** denotes reliability or probability of non-failure,

$$R_3\{X_1\cap X_2\cap X_3\} = R\{X_1|X_2\cap X_3\}R\{X_2|X_3\}R\{X_3\}. \quad (3.15)$$

Assuming now that the component is made up of many elements and the reliability of each is independent,

$$R_N = R\{X_1 \cap X_2 \cap X_3 \cap \ldots \cap X_N\} = R\{X_1\}R\{X_2\}R\{X_3\}\ldots R\{X_N\}. \tag{3.16}$$

R_N denotes the component reliability as a product of the reliabilities of its elements. This formulation correlates to the physics behind fatigue failure.

IV. MODERN DAMAGE ACCUMULATION METHODOLOGY

A. PROBABILISTIC MODEL

To obtain an accurate reliability estimate from direct testing, with a reasonable degree of certainty, requires testing a number of samples an order of magnitude greater than the desired reliability. The desired reliability for a military aircraft is one failure in 100000 (or $1\text{-}10^{-5} = 0.99999$). Thus at least a million samples would have to be tested for a statistical approach.

Nonetheless, an analytical model can be used to determine the probability with limited data or testing. The probabilistic model can be based on experience and an understanding of the physical phenomena. Engineering models are formulated from a prudent identification of the underlying physical process and application of mathematics to model the physics.

Fatigue damage depends on the applied stress level and duration of load. Hence, the general form of the cumulative distribution function (CDF or F) of fatigue must be a joint distribution of stress (S) and time (t) $\Rightarrow F(S,t)$. A general probabilistic distribution function for failure time was proposed by B. Coleman [Ref. 1] and incorporated by Phoenix and Wu [Ref. 7:p. 139]:

$$F(t|S) = 1 - \exp\left\{ -\Psi\left(\int_0^t \kappa\left(S(\xi)\right) d\xi \right) \right\} \quad , t \geq 0 \qquad (4.1)$$

where $S(t)$, $t \geq 0$ is the stress history, $\kappa(\bullet)$ is a special function called the breakdown rule, and $\psi(\bullet)$ is called the shape function.

B. FLAW DISTRIBUTION

Intrinsic flaws for brittle and ductile failure are related to crack size (a) and dislocation density (d), respectively. Flaws are a random occurrence, intrinsic to the material and manufacturing process. Failure occurs when the crack size or dislocation

density exceeds a critical value. The probability of occurrence of flaws greater than critical within metric volumes of the structural component is binomially distributed (a concise summary can be found in Lewis [Ref. 8:p. 22]):

$$f_B(n) = C_n^N p^n (1-p)^{(N-n)} \tag{4.2}$$

where p is the probability the flaws are greater than the critical value:

$p = P(a > a_c \text{ or } d > d_c)$;

and N = number of metric volumes

n = number of flaws $a > a_c$ or $d > d_c$

For a serviceable aircraft component, the probability of occurrence of a flaw greater than the critical value within any metric volume must be very small. When the critical flaw density is low ($p \ll 1$), and the number of metric volumes is large ($N \gg 1$), then

$$\ln(1\text{-}p) \cong \text{-}p \tag{4.3}$$

and the binomial distribution reduces to the Poisson distribution [Ref. 8:p. 149]:

$$f_B(n) \Rightarrow f_P(n) = \left(\frac{\mu^n}{n!}\right) e^{-\mu} \tag{4.4}$$

where μ is the location parameter. Furthermore, in fatigue, the location parameter of the distribution of flaws is time dependent. As time increases, flaws increase and the probability that the flaws exceed the critical value increases. In summary, the flaws in a component have a Poisson distribution.

C. LIFE DISTRIBUTION

For any given instant of time, in order for a component to have life τ, each of its elements or metric volumes must have life τ. When the weakest link fails the component fails. In the case of the P-3, the critical components consist of elements or links in the chain. Furthermore, the failure mechanism is assumed to be homogeneous. In other words, the failure process for the component is the same for the metric volume. A larger

component will have more elements, but the flaw distribution does not change. When this is true, the shape function defined as $\psi(\tau)$ takes on the Weibull form:

$$\psi(\tau) = \tau^{a} \tag{4.5}$$

where τ is the life of a single element, and **a** is the number of elements in the component. $\psi(\tau)$ is increasing and unbounded, meaning that the component has a finite life. The resulting CDF follows:

$$F(t|S) = 1 - \exp\{-\Psi(\tau)\} \tag{4.6}$$

where

t = the random variable time

$\tau = t/\hat{t}$; $\hat{t}$ is some intrinsic (normalizing) time constant

Note that this Weibull life distribution has an underlying Poisson flaw distribution, as previously described.

D. DAMAGE ACCUMULATION VIA LIFE CONVOLUTION

The intrinsic normalized life, τ, for a given stress history, $S(t)$, is obtained by convoluting the effect of stress via the breakdown rule $\kappa(\bullet)$:

$$\tau \equiv \frac{1}{\hat{t}} \int_{t_i}^{t_f} \kappa(S(t))dt \tag{4.7}$$

where $\hat{t}$ is a non-dimensionalizing and normalizing parameter for time, t_i is the initial time, t_f is the final time, and $\kappa(S(t))$ is a damage function. Hence, τ is the fractional life consumed. This process accumulates fractional fatigue damage, in a fashion similar to the conventional methodology described in Chapter II, which applied the rainflow-counting algorithm to Miner's rule.

Substitution of Eq 4.7 into Eq. 4.5 and then the result into Eq. 4.6 yields the following equation:

$$F(t|S) = 1 - \exp\left\{ -\left[\frac{1}{\hat{t}} \int_{t_i}^{t_f} \kappa(S(t))dt \right]^a \right\} \tag{4.8}$$

Stated in words Eq. 4.8 is the probability of failure of the component given its stress history, S(t), the time at which the probability is desired, t, the damage function, $\kappa(S(t))$, and its parameters.

Different physical processes give rise to different forms of the damage function $\kappa(S(t))$. Several forms of $\kappa(S(t))$ are frequently used in engineering. In the case of this research, the power form and exponential form are explored. Combinations of these two forms are also possible.

1. Power Law Damage Function

The first proposed damage function is based on the power law. This form has been observed to fit low cycle fatigue data in metals associated with yielding. The power form is:

$$\kappa(S(t)) \equiv \left(\frac{S(t)}{C_1} \right)^b \tag{4.9}$$

where b is a constant exponent, and C_1 is a constant non-dimensionalizing parameter for stress. Hence, $S(t)/C_1$ is the normalized stress history. Both b and C_1 are material constants. The constants are determined by fitting a line to Stress-Life (S-N) data for a given material in log space where:

$$b = \frac{1}{\text{slope}} \tag{4.10}$$

$$C_1 = \text{intercept} \tag{4.11}$$

and b is always negative. The power form plots as a straight line on the log-log axis, as shown in Figure 4.1:

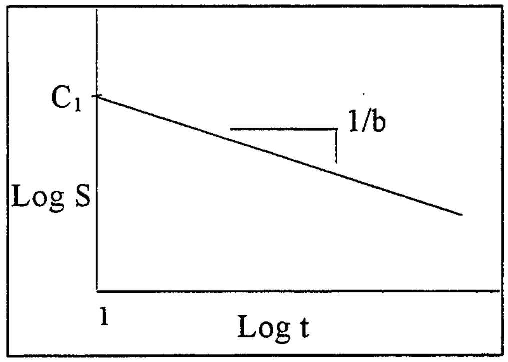


Figure 4.1

Substituting Eq. 4.9 into Eq. 4.8 yields:

$$F(t|S) = 1 - \exp\left\{-\left[\frac{1}{\hat{t}}\int_{t_i}^{t_f}\left(\frac{S(t)}{C_1}\right)^b dt\right]^a\right\} \tag{4.12}$$

Next, the parameters from the life test are related to the parameters in standard Weibull form. The standard Weibull reliability function is:

$$R(t) = 1 - F(t) = \exp\left\{-\left(\frac{t}{\beta_t}\right)^{\alpha_t}\right\} \tag{4.13}$$

where R(t) is the probability that the component has not failed in time t, β_t is a scale or location parameter for life, and α_t is the life shape parameter.

Equation 4.12 is written in terms of reliability, R(t|S), and equated to Eqn. 4.13:

$$\exp\left\{-\left(\frac{1}{\hat{t}}\int_{t_i}^{t_f}\left(\frac{S(t)}{C_1}\right)^b dt\right)^a\right\} = \exp\left\{-\left(\frac{t}{\beta_t}\right)^{\alpha_t}\right\} \tag{4.14}$$

The elements of Eq. 4.14 are known; $\hat{t}$ is an arbitrary normalizing parameter, C_1, b, β_t, and α_t are determined from material testing. **a** is the size effect parameter, which is unity if the

test specimens are the same size as the actual part. Given a stress history, Eq. 4.14 can be solved for the life t.

2. Exponential Form Damage Function

The second proposed damage function is defined using an exponential form. This form has been observed to fit high cycle fatigue data in metals associated with flaw growth. The exponential form is:

$$\kappa\left(S(t)\right) \equiv \frac{1}{C_2}\exp\left(\frac{S(t)}{C_3}\right) \tag{4.15}$$

where C_2 is a constant and C_3 is a constant non-dimensionalizing parameter for stress. Both C_2 and C_3 are material constants. These constants are determined by fitting a line to Stress-Life data for a given material in semi-log space where:

$$C_3 = \text{slope} \tag{4.16}$$

$$C_2 = \exp(\text{intercept}/C_3) \tag{4.17}$$

The exponential form plots as a straight line on semi-log axes, as shown in Figure 4.2:

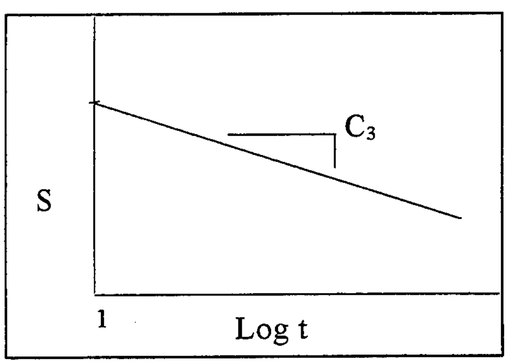


Figure 4.2

V. PROBABILISTIC INFORMATION THEORY

A. BAYESIAN ANALYSIS

Bayesian analysis involves expressing subjective knowledge about model parameter values as an *a priori* distribution for them. This distribution is then mathematically combined with observed data to yield the posterior distribution for the parameter values. The posterior distribution reflects the added information from the data and is narrower than the *a priori* distribution. The posterior yields a Bayesian estimate and probability limits for the true parameter values.

The Bayesian approach to sequential testing uses a posterior probability statement that is continually updated as new test data become available. Bayesian statistics combine subjective judgment or experience with hard data to provide probabilistic estimates. The Bayesian approach is based on the following equation which is a version of Bayes' theorem:

$$P\{A|B\} = \frac{P\{B|A\}P\{A\}}{P\{B\}} \qquad (5.1)$$

Here $P\{A\}$ is the prior probability of the event A before the information about B becomes available, and $P\{A|B\}$ is the posterior probability of A based on the information.

B. AN EXAMPLE OF BAYESIAN INFERENCE

Bayes inference after *one* outcome Y from $\{X\}$ can be written by conditional probability as in Eq. 5.1:

$$P\{X_i|Y\} = \frac{P\{Y|X_i\}P\{X_i\}}{P\{Y\}} \qquad (5.2)$$

By Law of Total Probability,

$$P\{Y\} = \sum_{i=1}^{n} P\{Y|X_i\}P\{X_i\} \qquad (5.3)$$

where $X_1, X_2, \ldots X_n$ are the only outcomes of $\{X\}$. Then considering only the event X_i, the Bayes inference after one outcome Y from the finite set X_k can be written as:

$$P\{X_i|Y\} = \frac{P\{Y|X_i\}P\{X_i\}}{\sum_{k=1}^{n} P\{Y|X_k\}P\{X_k\}} \tag{5.4}$$

A hypothetical scenario will now be worked out to demonstrate the usefulness of Bayesian inference. Consider two fatigue analysis methods which are used to estimate the life of the P-3 aircraft after corrosion eradication. Method A estimates 30,000 additional flight hours until first failure; method B estimates 12,000 additional flight hours until first failure. These methods are considered to be equally valid. Given these estimates, one refurbished P-3 is ground tested for 6,000 hours with no failure observed.

In light of the 6,000 hours of test time, this example will determine the weighted validity of method A and B respectively, as well as determine an upgraded estimate of the time to first failure (TTFF). The following variables are assigned:

t := test hours simulating a given flight profile
X_A := the event that TTFF by Method A is correct
X_B := the event that TTFF by Method B is correct
Y := testing hours to first failure

Because of equal weighting and the possibility of only two outcomes, the *prior* probabilities, that method A or method B is correct, are:

$$P\{X_A\} = 0.5$$
$$P\{X_B\} = 0.5$$

Before testing, equal weighting of the estimates gives:

$$\begin{aligned} TTFF &= X_A P\{X_A\} + X_B P\{X_B\} \\ &= (30{,}000)(0.5) + (12{,}000)(0.5) = 21{,}000 \text{ flight hours} \end{aligned} \tag{5.5}$$

To quantify $P\{Y\}$, a distribution function is required. For purposes of this example a constant failure rate model is assumed (whereas finding the proper model and estimating its parameters is the focus of this research):

$$P\{Y|X_i\} = \exp(-t \,/\, TTFF_i) \tag{5.6}$$

then:

$$P\{Y|X_A\} = e^{-6000/30000} = 0.819$$
$$P\{Y|X_B\} = e^{-6000/12000} = 0.607$$

Now the appropriate values are substituted into Eq. 5.4 for each prediction method:

$$P\{X_A|Y\} = \frac{(0.819)(0.5)}{(0.819)(0.5)+(0.607)(0.5)} = 0.574$$

$$P\{X_B|Y\} = \frac{(0.607)(0.5)}{(0.819)(0.5)+(0.607)(0.5)} = 0.425$$

Where $P\{X_A|Y\}$ and $P\{X_B|Y\}$ are the revised probabilities that method A and method B, respectively, are correct in light of the 6,000 hours of testing.

Given the revised weighting of the methods a new estimate of the TTFF is obtained from Eq. 5.5:

$$\begin{aligned} TTFF &= X_A P\{X_A\} + X_B P\{X_B\} \\ &= (30{,}000)(0.574) + (12{,}000)(0.425) = 22{,}300 \text{ flight hours} \end{aligned}$$

The updated information has been obtained even though no failure has been observed in the testing.

C. MAXIMUM LIKELIHOOD ESTIMATION

Point estimation uses observed data (realized random variables) in order to gain information about an unknown characteristic of the physical phenomena. Suppose X, the random variable, is the intrinsic value of a specimen chosen at random from a population. Then x, the realized random variable, is the value measured from an experiment. Furthermore, $f(x;\theta)$ is the probability distribution function (pdf) that reflects the distribution of individual measurements in the population. Based on experience and the underlying physics, it may be reasonable to assume the type of distribution that $f(x;\theta)$ represents, where θ is an unknown parameter such as the mean or variance of the distribution. Point estimation assigns a value to θ based on the experimental data.

One rudimentary method of parameter estimation is by a least squares fit of linearized data. However, least squares provides an equal weighting of the data which does not account for data cluster. A better, but more sophisticated, method called the Maximum Likelihood Estimate (MLE) weights the data by probability. Assume that a set of n independent random variables, $X_1, X_2, \ldots, X_n$, each with pdf $f(x;\theta)$, will be observed, resulting in a set of data $x_1, x_2, \ldots, x_n$. Then the joint density function for the observations can be written as the *likelihood* function, $L(\theta)$:

$$L(\theta) = f(x_1;\theta)\, f(x_2;\theta) \ldots f(x_n;\theta) \tag{5.7}$$

The *maximum likelihood* can be obtained by taking the derivative of $L(\theta)$ with respect to θ and setting it equal to zero. Hence, MLE chooses the value of θ that gives a higher likelihood of observing the given set of data.

Many statistical software packages contain MLE routines, but typically they are limited to analysis of exact data ($x = x_i$). Such software does not handle censored data ($x > x_i$ or $x < x_i$) and interval data ($x_{i-1} < x < x_i$). In the case of fatigue, exact data represents i number of specimen all tested until failure. Right censored data can be described by analogy of testing a specimen for a given number of fatigue cycles and then terminating the test prior to failure. Left censored data can be described by analogy of a specimen failing but the equipment counter continues to count fatigue cycles. Interval data can be described by analogy of a faulty counter that does not register cycles until a value of say 5000, and a specimen fails before 5000 cycles are reached.

These types of data can describe the fatigue life of a given P-3 parked on the flight line. As an example of right censored data, the aircraft's history up to date may be known and no failure has occurred. In that case, the aircraft is analogous to the specimen. On a different level, one must consider these different types of data sets to evaluate the expected fatigue life of post-SRP aircraft that will contain various mixes of new and old components. In this case, a wing or some other sub-structural component is analogous to the specimen.

At NPS, Professor Edward M. Wu has developed a sophisticated MLE software package for this research that handles exact, censored, and interval data. The MLE software has several uses. Besides estimating parameters of an exact data set, it can be used to determine how much testing will be required to get an adequate representation of an underlying distribution. Furthermore, the nature of a distribution can be explored via a coupling of the MLE software to a Monte Carlo analysis on multiple sets of simulated data.

D. AN APPLICATION OF MAXIMUM LIKELIHOOD ESTIMATION

Consider the set of 15 data points resulting from the failure of Aluminum 7075-T6 coupon specimens tested at a fully reversed stress of 30,900 psi. The number of cycles to failure for each are listed in Table 5.1:

Specimen	Cycles (N)
1	32936
2	38653
3	39149
4	45330
5	46619
6	49060
7	52180
8	53535
9	61247
10	68189
11	70194
12	74580
13	78456
14	81847
15	89906

Table 5.1 "Exact" Data

Using MLE the shape (α) and scale (β) parameters for a Weibull pdf have been computed from the exact data listed in Table 5.1:

$$\alpha = 3.84601$$
$$\beta = 65146.9$$

These parametric values can be substituted into the Weibull pdf, Eq. 5.8:

$$f(x;\alpha,\beta) = \frac{\alpha}{\beta}\left(\frac{x}{\beta}\right)^{\alpha-1} e^{\left(-\left(\frac{\alpha}{\beta}\right)^{\alpha}\right)}, 0 \le x \le \infty \tag{5.8}$$

Given the numeric values for α and β the Weibull pdf for the exact data is plotted in Figure 5.1:

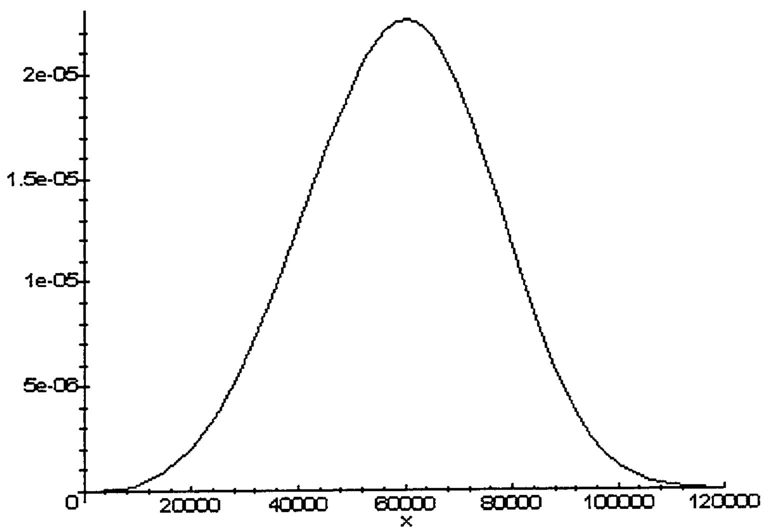


Figure 5.1 Weibull pdf of Table 5.1 data

VI. ALUMINUM 7075-T6 FATIGUE DATA BASE

A. INTRODUCTION

Experimental fatigue data is required for any analytical approach to life prediction. Conventional life prediction methods, like the Fatigue Life Program (FLP) developed at the Naval Postgraduate School (NPS) and the Fatigue Analysis of Metallic Structures (FAMS) program used by AeroStructures, Inc. (ASI), utilize historical or estimated fatigue data to calculate fatigue life expended or fatigue life remaining. Furthermore, the successful development of a generalized probabilistic fatigue life prediction model depends on a careful coupling of experimental data and probabilistic information theory.

As stated in Chapter I, hot spot No. 12 (Wing Station 209, lower front spar web) is the fatigue critical area for most P-3 aircraft. The spar web is made of Aluminum 7075-T6 sheet. Therefore, a database for this material has been compiled in the Appendices. Although the bulk of the data comes from literature sources, some of it was generated from testing at NPS.

Note that most S-N data is published (as in MIL-HDBK-5) in the form of S-N curves. As discussed in Chapter III, these S-N curves reflect an "average" and do not include life variability. Typically the raw data is not published and difficult to locate. In fact, some labs no longer have their original data. It is believed that the data compiled for this thesis will eventually provide a better understanding of fatigue life prediction.

The remainder of this chapter will describe the type of data included in the Appendices. The data includes constant amplitude and spectral fatigue for both axial and rotational tests. The variables, required to categorize each test, include the specimens' surface finish, the type of load applied, frequency of load, and size of specimen. This type of amplifying information, as well as drawings of the test specimens have been cataloged in an effort to provide a useful, one-source database.

B. NOTATION AND TERMINOLOGY

Each table of data included in the Appendices has a common header containing terms or variables which will now be described:

R—the ratio of minimum stress to maximum stress in the cycle.

Mean Stress—maximum stress plus minimum stress divided by two.

Kt—theoretical elastic stress-concentration factor.

Notch Type—stress-concentrations were produced from central holes, edge-cut notches, or fillet-type notches.

Thickness—thickness of coupon specimen, in inches.

Width—gross dimension in inches; does not include subtraction of central-hole or notch.

N. Width—net dimension in inches; only accounts for material widths at net section i.e., dimension of hole or notch has been subtracted.

Gross Area vs. Net Area—see Figure 6.1 below:

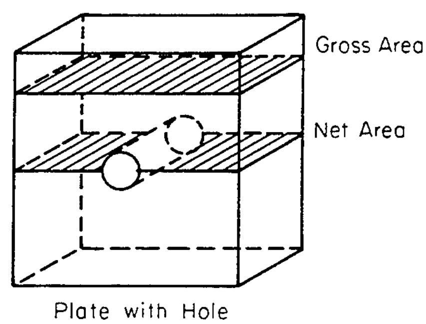


Figure 6.1 "Gross" vs. "Net" [Ref. 2:p. 139]

Load Direction—axial for sheet material; due to availability some rotational data was included for extruded rods.

Load Shape—in most cases the cyclic fatigue loads were sinusoidal. However, some of the NACA testing applied a "sawtooth" load-time cycle as shown in Appendix F.

Frequency—of applied load cycle in hertz.

Frequency—of applied load cycle in hertz.

Specimen—type, either a sheet-material coupon or extruded rod.

Finish—surface polished or unpolished.

Smax—the maximum stress for each specimen computed for the area of the net cross section.

N—cycles to failure.

+ (after data)—indicates right censored data where the specimen did not fail (runout).

* (after data)—indicates right censored data where the specimen failed in the grips or away from test section.

-- (after data)—indicates left censored data where the specimen failed but the counter continued to accumulate cycles (i.e., no cutoff of equipment at failure).

>,< (before data)—indicates interval censored data where the specimen failed in an interval between two known counts (note, two numbers required for data entry).

Other terms will be addressed when appropriate to describe particular data sets. The tabular fatigue data has been divided into four appendices:

Appendix A—CONSTANT AMPLITUDE, AXIAL FATIGUE

Appendix B—SPECTRAL, AXIAL FATIGUE

Appendix C—CONSTANT AMPLITUDE, ROTATIONAL FATIGUE

Appendix D—SPECTRAL, ROTATIONAL FATIGUE

Other related appendices:

Appendix E—SPECIMEN DRAWINGS (Provided for analysis of size and other geometrical effects.)

Appendix F—NACA "SAWTOOTH" LOAD SHAPES

Appendix G—DEVELOPMENT OF GUST AND MANEUVER LOADING SPECTRA

Appendix H—ROTATIONAL LOAD SHAPE SPECTRA

The following sections include amplifying information that is not contained in the appendices.

C. PRELUDE TO APPENDIX A

Appendix A contains data for unnotched and notched sheet specimens tested in an axial direction under a *constant amplitude* cyclic fatigue load. The first table contains data generated for this thesis; the testing was done on a MTS Model 810 test machine acquired by NPS in 1975 (similar to the 1985 MTS machine Smith describes in detail in Ref. 9). Smith used a 458 controller vice a 442 controller. Smith tested in strain control to produce strain-life data. The data for this thesis was produced using load control.

D. PRELUDE TO APPENDIX B

Appendix B contains data for notched sheet specimens tested in an axial direction under a *spectral* fatigue load. Because the aircraft operates in a complex physical environment it experiences an extensive service loading to include: gust loadings, maneuver loadings, landing impacts, taxiing and ground handling, ground-air cycle, buffeting, and acoustical noise. The contribution of some of these types of loading to fatigue damage is controversial. Nevertheless, fatigue spectra consisting of various loads were decomposed by Lockheed from a 96 minute flight data recording of a B-47, in accordance with MIL-A-8866.

Various combinations of the above spectral service loadings were applied in coupon tests. The tables in Appendix B contain terminology that can be explained by a brief development of gust and maneuver loading histories. For clarification, Appendix G contains a pictorial development of gust and maneuver loading spectra. To correctly interpret the data one must understand the difference between *ordered* and *random* loading histories, as well as the terms *varying* stress and *incremental* stress.

In short, gust loading is characterized by a varying stress component oscillating about a substantially constant mean load level. *Low peak data* is taken from a load history with varying stress oscillating about a lower mean stress than that for *high peak data*. Maneuver loading is characterized by incremental stresses rising above and then returning to a steady state or minimum stress. Ordered loading histories eliminate the natural

random sequence. The regrouped load cycles for an ordered history are repeated in a block. Hence, the failure of a coupon tested under an ordered history is recorded by the number of blocks to failure.

E. PRELUDE TO APPENDIX C

Appendix C contains data for unnotched and notched extruded rod specimens tested in rotation under a *constant amplitude* cyclic fatigue load. Since all tests were conducted in rotating-beam fatigue testing machines, stresses were completely reversed in all tests (i.e., $R = -1$).

F. PRELUDE TO APPENDIX D

Appendix D contains data for unnotched and notched extruded rod specimens tested in rotation under *varying amplitude* stress. Since all tests were conducted in rotating-beam fatigue testing machines, stresses were completely reversed in all tests. Two loading spectra were employed; one produced a stress amplitude that modulated sinusoidally with time and the other modulated according to an exponential function. A modulation cycle repeated after every 10,000 revolutions of the specimen. Figures of these two modulated load shapes are shown in Appendix H for clarification.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

A satisfactory analytical prediction for the problem of fatigue life has been the elusive goal of some of the best scientists and engineers for over 160 years. The difficulty is due to the numerous variables involved, interactive failure mechanisms, the statistical qualities of nature, and the limitations of conventional stress analysis. For example, the micro-detailed geometrical fatigue analysis required at many points throughout a complex structure remains beyond the capabilities of the modern analysts. For these reasons, it is believed that a probabilistic fatigue life prediction model can be developed to provide a generalized and satisfactory solution.

As stated in Chapter III, a probabilistic approach may add real value to the contemporary methods for predicting reliability and readiness of Naval aircraft. From a reliability perspective, the probability of having one failure of a hot spot on a specific aircraft at a given number of flight hours can be determined. Similarly from a readiness point of view, the number of aircraft, fleet wide, which will need to be reworked to keep the probability of failure below a reliability target can be determined.

The development of a generalized probabilistic model warrants further research to enhance the scientific progress which will foster the safety, readiness, and reliability of aging aircraft fleets. The primary approach must be experimental. Due to expense and the statistics of a limited number of samples, experimental data must be coupled with probabilistic information theory if life variability is to be adequately predicted.

B. RECOMMENDATIONS

As a result of the research performed in this thesis, the following recommendations for further study are provided:

1. Continue data base compilation from literature sources, and generation from laboratory testing. Place tabulated results on an Internet web site as a good will measure to stimulate and foster the sharing of precious fatigue data.

2. Continue constant amplitude testing of *new* 7075-T6 coupon specimens. Test *old* coupon specimens of 7075-T6 (with known service history) removed from SRP refurbished aircraft. Conduct spectrum testing for modified flight profiles on *new* and *old* coupons. Use results to assess the residual life of current fleet aircraft.

3. Input the data into the Fatigue Life Program (FLP) and Fatigue Analysis of Metallic Structures (FAMS) software to assess the conventional fatigue life prediction methodologies.

4. Use the data to verify that the methodology for modern damage convolution includes the prediction of fatigue life variability.

5. Use an existing finite element model of the P-3 written by ASI to establish loading and boundary conditions for laboratory tests of critical structural components.

6. Conduct structural fatigue testing on a wing substructure available from a SRP core kit. The wing substructure, as specified, will consist of a section of the wing box (which includes spars, caps, planks and ribs) from WS 140 to WS 235. This is the section of the wing that houses the inboard engines and landing gear. It contains several hot spots, including the primary critical locations at WS 209 and WS 167. Testing will allow lead time to forewarn any refurbishment of fleet aircraft.

7. Apply Bayesian inference formulation. Even if no failure occurs in the structural testing, probability can be used to assess the fleet's reliability and material readiness posture. Probabilistic information theory will be required to assess the life prediction of post-SRP aircraft, which will contain a mixture of new and old components.

LIST OF REFERENCES

1. Coleman, B.D., *Journal of Applied Physics,* vol. 29, pp. 968-983.

2. Bannantine, J.A., Cromer, J.J., and Hardroc, J.L., *Fundamentals of Metal Fatigue Analysis,* Prentice-Hall, Inc., 1990.

3. Skelly, M.V., *Fatigue Life Program Using Strain-Life Methods,* Master's Thesis, Naval Postgraduate School, March 1993.

4. Fuchs, H.O., *Metal Fatigue in Engineering,* John Wiley & Sons, Inc., 1980.

5. Kapur, K.C. and Lamberson, L.R., *Reliability in Engineering Design,* John Wiley & Sons, Inc., 1977.

6. Nelson, W., *Accelerated testing: Statistical Models, Test Plans, and Data Analysis,* John Wiley & Sons, Inc., 1990.

7. Phoenix, S.L., and Wu, E.M., "Statistics for the Time Dependent Failure of Kevlar-49 Composites: Micromechanical Modeling and Data Interpretation," *Mechanics of Composite Materials: Recent Advances.* Ed. Zvi Hashin and Carl T. Herakovich. Pergamon Press, 1982, pp. 135-162.

8. Lewis, E.E., *Introduction to Reliability Engineering,* John Wiley & Sons, Inc., 1986.

9. Smith, B.L., *Mean Strain Effects on the Strain Life Fatigue Curve,* Master's Thesis, Naval Postgraduate School, March 1993.

10. Smith, C.R., *A Method for Estimating the Fatigue Life of 7075-T6 Aluminum Alloy Aircraft Structures,* Naval Air Engineering Report No. 1096, April 1965.

11. Smith, C.R., *S-N Characteristics of Notched Specimens,* NASA CR-54503, 1966.

12. "ALCOA Facsimile: Mechanical Test Results, October-December 1991", ALCOA Technical Center Facsimile sent to Naval Postgraduate School.

13. Grover, H.J., Bishop, S.M., and Jackson, L.R., *Fatigue Strengths of Aircraft Materials: Axial-Load Fatigue Tests on Unnotched Sheet Specimens of 24S-T3 and 75S-T6 Aluminum Alloys and of SAE 4130 Steel,* NACA TN 2324, 1951.

14. Illg, W., *Fatigue Tests on Notched and Unnotched Sheet Specimens of 2024-T3 and 7075-T6 Aluminum Alloys and of SAE 4130 Steel With Special Consideration of the Life Range From 2 to 10,000 Cycles*, NACA TN 3866, 1956.

15. Smith, C.R., *Evaluation of Fatigue Life of Chrome-ite Plated Specimens*, Air Force Flight Dynamics Laboratory Project No. AF-1467, Wright-Patterson Air Force Base, Ohio, December 1965.

16. Smith, C.R., *Linear Strain Theory and the Smith Method for Predicting Life of Metals and Structures for Spectrum Loading*, Aerospace Research Laboratories Report ARL 64-55, April 1964, Wright-Patterson Air Force Base, Ohio.

17. Grover, H.J., Bishop, S.M., and Jackson, L.R., *Fatigue Strengths of Aircraft Materials: Axial-Load Fatigue Tests on Notched Sheet Specimens of 24S-T3 and 75S-T6 Aluminum Alloys and of SAE 4130 Steel With Stress Concentration Factors of 2.0 and 4.0*, NACA TN 2389, 1951.

18. Grover, H.J., Bishop, S.M., and Jackson, L.R., *Fatigue Strengths of Aircraft Materials: Axial-Load Fatigue Tests on Notched Sheet Specimens of 24S-T3 and 75S-T6 Aluminum Alloys and of SAE 4130 Steel With Stress Concentration Factor of 5.0*, NACA TN 2390, 1951.

19. Grover, H.J., Hyler, W.S., and Jackson, L.R., *Fatigue Strengths of Aircraft Materials: Axial-Load Fatigue Tests on Notched Sheet Specimens of 24S-T3 and 75S-T6 Aluminum Alloys and of SAE 4130 Steel With Stress Concentration Factor of 1.5*, NACA TN 2639, 1952.

20. Hardrath, H.F., and Illg, W., *Fatigue Tests at Stresses Producing Failure in 2 to 10,000 Cycles. 24S-T3 and 75S-T6 Aluminum-Alloy Sheet Specimens With a Theoretical Stress-Concentration Factor of 4.0 Subjected to Completely Reversed Axial Load*, NACA TN 3132, 1954.

21. Landers, C.B., and Hardrath, H.F., *Results of Axial-Load Fatigue Tests on Electropolished 2024-T3 and 7075-T6 Aluminum-Alloy-Sheet Specimens With Central Holes*, NACA TN 3631, 1956.

22. Grover, H.J., Hyler, W.S., and Jackson, L.R., *Fatigue Strengths of Aircraft Materials: Axial-Load Fatigue Tests on Edge-Notched Sheet Specimens of 2024-T3 and 7075-T6 Aluminum Alloys and of SAE 4130 Steel With Notch Radii of 0.004 and 0,070 Inch*, NASA TN D-111, 1959.

23. Naumann, E.C., Hardrath, H.F., and Guthrie, D.E., *Axial-Load Fatigue Tests of 2024-T3 and 7075-T6 Aluminum-Alloy Sheet Specimens Under Constant-and Variable-Amplitude Loads*, NASA TN D-212, 1959.

24. Crichlow, W.J., *An Engineering Evaluation of Methods for the Prediction of Fatigue Life in Airframe Structures*, Air Force Flight Dynamics Laboratory Project No. AF-1367, Wright-Patterson Air Force Base, Ohio, March 1962.

25. Hardrath, H.F., Utley, E.C., and Guthrie, D.E., *Rotating-Beam Fatigue Tests of Notched and Unnotched 7075-T6 Aluminum-Alloy Specimens Under Stresses of Constant and Varying Amplitudes*, NASA TN D-210, 1959.

BIBLIOGRAPHY

O'Connor, J.O., *Probabilistic Reliability Modeling of Fatigue on the H-46 Tie Bar*, Master's Thesis, Naval Postgraduate School, September 1994.

Sauter, G.P., *Durability Modeling and Design of a Helicopter Rotor Tie Bar*, Master's Thesis, Naval Postgraduate School, September 1995.

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NPS [Kousky]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
-1	0	1	None	0.125	0.375
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	5	Sheet	See Below	

Smax (KSI)	N	Finish	Smax (KSI)	N	Finish
30.9	32936	Unpolished	30.9	84452	Polished
30.9	38653	Unpolished	30.9	86658	Polished
30.9	39149	Unpolished	30.9	119502	Polished
30.9	42518	Unpolished	25.6	83595	Unpolished
30.9	45330	Unpolished	25.6	85059	Unpolished
30.9	45541	Unpolished	25.6	110733	Unpolished
30.9	46619	Unpolished	25.6	118506	Unpolished
30.9	49060	Unpolished	25.6	125110	Unpolished
30.9	52150	Unpolished	25.6	169926	Unpolished
30.9	52180	Unpolished	25.6	175586	Unpolished
30.9	53535	Unpolished	25.6	181927	Unpolished
30.9	54676	Unpolished	25.6	211932	Unpolished
30.9	56482	Unpolished	25.6	279772--	Unpolished
30.9	61247	Unpolished	25.6	370207*	Unpolished
30.9	68189	Unpolished	25.6	410411*	Unpolished
30.9	70194	Unpolished	25.6	>454000	Unpolished
30.9	74580	Unpolished		<902905	
30.9	78456	Unpolished	25.6	472635*	Unpolished
30.9	81847	Unpolished	25.6	487092+	Unpolished
30.9	89906	Unpolished	25.6	492156*	Unpolished
30.9	130898--	Unpolished	25.6	492764*	Unpolished
30.9	360671--	Unpolished			

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NPS [Ref. 9:p. 39]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Strain	Kt	Notch Type	Thick. (in)	Width (in)
-1	0	1	None	0.125	0.375
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	10	Sheet	Not Polished	

STRAIN:	0.007	0.005	0.003	0.0025
CYCLES:	971	21884	79316	897702
	1002	22046	84150	899463
	1261	24821	87636	900983
	2200	25783	87768	911760
	2489	26662	88058	929722
	2500	27663	91271	948989
	2660	30013	100540	956620
	2783	31468	108722	1000654
	3015	32266	116234	1100362
	3426	38904	121783	1140783
	3624	41768	125777	1180456
	3642	42036	126239	1221588
	3681	42255	147686	1259846
	3843	44016	176532	1270138
	4013	44322	177003	1302555
	4100	45167	178180	1359872
	4226	47562	204188	1364563
	4512	49127	204984	1381112
	4672	58236	217489	1390046
	5080	62000	224254	1400012

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NPS [Ref. 9:p. 40]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Strain	Kt	Notch Type	Thick. (in)	Width (in)
N/A	0.03	1	None	0.125	0.375
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	10	Sheet	Not Polished	

STRAIN:	0.007	0.005	0.003	0.0025
CYCLES:	1348	2014	50265	70015
	1512	2235	50987	96548
	1597	2477	51331	97036
	1704	2506	52242	101047
	1812	2896	53310	117108
	1987	3135	55204	202111
	2056	3152	56897	266504
	2144	3290	56943	307564
	2247	3438	58883	399176
	2369	3526	59468	445563
	2438	3603	60014	458118
	2527	3668	61156	497063
	2604	3789	61783	595181
	2756	3880	63464	686744
	2844	3997	64987	701168
	2997	4002	66663	707984
	3016	4176	68007	862564
	3111	4651	70977	887032
	3244	5200	71149	887564
	3650	5240	72465	1107363

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NPS [Ref. 9:p. 41]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Strain	Kt	Notch Type	Thick. (in)	Width (in)
N/A	0.063	1	None	0.125	0.375
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	10	Sheet	Not Polished	

STRAIN:	0.007	0.005	0.003	0.0025
CYCLES:	1030	1206	7500	12940
	1106	1370	10003	32431
	1202	1846	13250	43250
	1252	2099	18057	50893
	1369	2204	21989	57122
	1483	2256	27003	59257
	1546	2275	34256	63587
	1661	2350	36651	70633
	1794	2403	40077	77752
	1817	2800	43001	80008
	1892	3101	43987	86554
	2054	3267	45554	90119
	2176	3311	50117	92655
	2234	3380	56462	99875
	2304	3580	60987	103003
	2457	3929	70543	109968
	2512	4238	74054	118578
	2606	4900	74988	119972
	2690	5650	75051	120875
	2735	5801	78239	146113

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NPS [Ref. 9:p. 42]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Strain	Kt	Notch Type	Thick. (in)	Width (in)
N/A	0.1	1	None	0.125	0.375
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	10	Sheet	Not Polished	

STRAIN:	0.007	0.005	0.003	0.0025
CYCLES:	776	1632	6246	13017
	812	1945	7732	13298
	946	2006	8501	14983
	1063	2037	8545	15564
	1097	2197	8601	16088
	1288	2256	8988	17599
	1327	2311	9234	18424
	1402	2434	9756	19312
	1459	2486	10008	20987
	1540	2528	14062	21897
	1605	2605	14783	22056
	1643	2747	15033	22987
	1706	2828	15507	24016
	2007	2897	16389	25987
	2046	2963	17422	26013
	2197	3069	19564	27883
	2373	3542	21018	28413
	2404	3711	28762	28997
	2456	3807	34413	29012
	2554	3850	34442	29135

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

CONVAIR [Ref. 10:p. 55]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
0.5	N/A	1	None	0.1	1
Load Dir.	**Load Shape**	**Freq. (Hz)**		**Specimen**	**Finish**
Axial	Sinusoidal	5 (N<=5000) 29.2 (N>5000)		Sheet	Polished

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
88.0	4	85.0	12000	67.0	90000
87.0	6	85.0	11600	67.0	95000
87.0	6	85.0	13000	67.0	126000
87.0	9	85.0	13520	65.0	83000
87.0	14	85.0	13650	65.0	75000
87.0	23	85.0	13950	65.0	92000
86.5	8	85.0	14000	65.0	103000
86.5	9	85.0	14640	65.0	114000
86.5	10	85.0	16000	65.0	134000
86.5	15	77.0	11000	65.0	135000
86.5	30	77.0	21000	60.0	51000
86.5	7580	77.0	25000	60.0	75000
86.5	8280	77.0	26000	60.0	98000
86.5	9250	77.0	26000	60.0	99000
86.5	9640	77.0	40000	60.0	282000
86.5	9850	77.0	44000	60.0	336000
86.5	10550	77.0	46000	60.0	511000
86.5	12070	77.0	46000	55.0	252000
86.0	5	72.0	33000	55.0	735000
86.0	90	72.0	47000	55.0	2132000
86.0	13030	72.0	49000	55.0	2820000
85.5	15	72.0	50000	55.0	6865000
86.5	18	70.0	63000	50.0	10000000+
85.0	6950	70.0	63000	50.0	10000000+
85.0	9200	67.0	57000		
85.0	11000	67.0	64000		

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

CONVAIR [Ref. 10:p. 56]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
0.25	N/A	1	None	0.1	1
Load Dir.	**Load Shape**	**Freq. (Hz)**		**Specimen**	**Finish**
Axial	Sinusoidal	5 (N<=5000) 29.2 (N>5000)		Sheet	Polished

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
88.0	7	65.0	17000	47.5	56000
87.0	10	65.0	21000	47.5	74000
86.5	5	65.0	21000	47.5	144000
86.5	2750	65.0	22000	47.5	195000
86.5	544	65.0	23000	47.5	221000
86.0	6	65.0	27000	45.0	68000
86.0	3490	65.0	33000	45.0	72000
86.0	2980	65.0	34000	45.0	92000
84.0	3590	65.0	38000	45.0	93000
82.5	5830	53.0	53000	45.0	236000
75.0	10000	53.0	64000	45.0	237000
75.0	16000	53.0	87000	45.0	7355000+
75.0	17000	53.0	294000	45.0	10360000+
75.0	16000	50.0	58000	35.0	10000000+
75.0	17000	50.0	62000	35.0	10000000+
75.0	17000	50.0	62000		
75.0	17000	50.0	117000		
75.0	18000	50.0	125000		
75.0	18000	50.0	147000		
75.0	19000	50.0	167000		

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

CONVAIR [Ref. 10:p. 57]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
0	N/A	1	None	0.1	1
Load Dir.	**Load Shape**	**Freq. (Hz)**		**Specimen**	**Finish**
Axial	Sinusoidal	5 (N<=5000) 29.2 (N>5000)		Sheet	Polished

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
87.0	12	75.0	6000	35.0	84000
87.0	15	75.0	9000	35.0	88000
87.0	55	75.0	10000	35.0	201000
87.0	1660	75.0	14000	35.0	212000
86.5	1215	70.0	9000	35.0	678000
86.5	1960	70.0	11000	35.0	1591000
86.5	2440	70.0	11000	35.0	2230000
86.5	2680	70.0	12000	35.0	2239000
86.5	2720	70.0	14000	35.0	2230000
86.5	3150	70.0	16000	35.0	4423000
86.0	1935	55.0	28000	35.0	7684000
86.0	2105	55.0	36000	35.0	15320000
86.0	2460	55.0	37000	32.5	1658000
86.0	2650	55.0	38000	32.5	4616000
85.0	1410	55.0	39000	32.5	10000000+
85.0	1710	45.0	60000	32.5	10000000+
85.0	2110	45.0	80000	25.0	1571000+
85.0	2470	45.0	81000	25.0	4455000+
85.0	2850	45.0	88000	25.0	6911000+
85.0	3060	45.0	99000	25.0	10000000+
84.0	3290	40.0	51000	25.0	10000000+
83.0	1800	40.0	52000	25.0	10000000+
83.0	2980	40.0	100000		
83.0	3200	40.0	130000		
83.0	3610	40.0	178000		
83.0	190				
83.0	250				
82.0	1095				
82.0	4155				
81.0	3030				
81.0	4540				

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

CONVAIR [Ref. 10:p. 58]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
-0.5	N/A	1	None	0.1	1
Load Dir.	**Load Shape**	**Freq. (Hz)**		**Specimen**	**Finish**
Axial	Sinusoidal	5 (N<=5000) 29.2 (N>5000)		Sheet	Polished

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
85.0	12	80.0	1000	50.0	27000
85.0	214	80.0	1073	40.0	35000
85.0	216	80.0	1195	40.0	51000
85.0	604	80.0	1270	40.0	52000
85.0	641	80.0	1248	40.0	72000
86.0	85	80.0	1635	40.0	83000
86.0	96	77.5	1698	25.0	152000
86.0	146	77.5	1266	25.0	209000
86.0	859	75.0	1483	25.0	241000
84.0	410	75.0	1887	25.0	271000
84.0	478	75.0	1920	25.0	271000
84.0	640	75.0	2275	22.5	405000
84.0	1025	75.0	2649	22.5	1200000+
83.0	850	75.0	2750	22.5	1200000+
83.0	1108	75.0	3049	22.5	1200000+
81.5	525	75.0	3999	22.5	1362000+
81.5	874	65.0	7000	19.0	1200000+
81.5	906	65.0	8000	19.0	1400000
81.5	996	65.0	9000	19.0	1701000+
81.5	1025	65.0	10000	19.0	1780000+
81.5	1427	65.0	10000	19.0	1998000*
81.5	1533	50.0	18000	19.0	1600000*
80.0	288	50.0	25000	19.0	2785000*
80.0	851	50.0	25000		
80.0	312	50.0	27000		

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

CONVAIR [Ref. 10:p. 59]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
-1	N/A	1	None	0.1	1
Load Dir.	**Load Shape**	**Freq. (Hz)**		**Specimen**	**Finish**
Axial	Sinusoidal	5 (N<=5000) 29.2 (N>5000)		Sheet	Polished

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
80.0	41	72.0	298	60.0	3630
80.0	74	72.0	302	60.0	4350
80.0	85	72.0	320	60.0	5510
80.0	101	72.0	530	50.0	11000
80.0	135	70.0	777	50.0	11000
80.0	140	70.0	825	50.0	13000
80.0	184	70.0	984	50.0	13000
80.0	207	70.0	1042	40.0	21000
77.5	101	70.0	1118	40.0	29000
77.5	140	70.0	1169	40.0	35000
77.5	155	70.0	1220	40.0	40000
77.5	197	70.0	1275	30.0	47000
78.0	55	70.0	2230	30.0	95000
78.0	120	70.0	3300	30.0	226000
78.0	196	65.0	2043	30.0	235000
78.0	209	65.0	2160	25.0	291000
75.0	285	60.0	2850	20.0	460000
75.0	312	60.0	3060	20.0	629000
75.0	360	60.0	3230	20.0	1220000+
75.0	600	60.0	3280	20.0	1200000+
75.0	885	60.0	3420	20.0	1200000+
75.0	1080	60.0	3600		

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

CONVAIR [Ref. 10:p. 60]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
-2	N/A	1	None	0.1	1
Load Dir.	**Load Shape**	**Freq. (Hz)**		**Specimen**	**Finish**
Axial	Sinusoidal	5 (N<=5000) 29.2 (N>5000)		Sheet	Polished

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
40.0	940	25.0	55000	17.5	569000
40.0	1620	25.0	71000	16.0	854000
40.0	2560	25.0	94000	15.5	12905000+
40.0	2985	25.0	111000	15.0	3406000*
35.0	3431	20.0	184000	15.0	3431000*
35.0	4520	20.0	272000	15.0	4343000*
35.0	8750	20.0	404000	15.0	5251000+
30.0	11200	20.0	412000	15.0	5498000*
30.0	22700	17.5	355000	15.0	10000000+
30.0	28320	17.5	378000	15.0	10000000+
30.0	28490	17.5	540000		

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
-4	N/A	1	None	0.1	1
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	5	Sheet	Polished	

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
22.5	5730	17.5	30000	12.5	628000
22.5	8980	15.0	159200	11.5	1680000
22.5	22100	15.0	162000	11.25	4348000
20.0	17300	15.0	168000	11.25	8867000+
20.0	19200	15.0	169000	11.0	10000000+
17.5	30000	12.5	382000		

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

CONVAIR [Ref. 11:p. 28]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
0	N/A	1	None	0.05	0.5
Load Dir.	**Load Shape**	**Freq. (Hz)**		**Specimen**	**Finish**
Axial	Sinusoidal	5 (N<=10000) 29.2 (N>10000)		Sheet	Polished

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
85.0	3360	55.0	33000	45.0	76000
85.0	3490	55.0	33500	45.0	134000
80.0	2985	55.0	35000	45.0	152000
80.0	4520	55.0	52000	45.0	259000
80.0	6840	55.0	59000	45.0	291000
75.0	4510	55.0	65000	45.0	625000
75.0	6330	55.0	76000	45.0	929000
75.0	8650	50.0	41000	45.0	1367000
65.0	18000	47.0	59000	45.0	1383000
65.0	20000	47.0	147000	42.5	76000
65.0	22000	47.0	298000	40.0	93000
65.0	18640	45.0	39000	40.0	620000
60.0	19000	45.0	57000	40.0	10000000+
60.0	28530	45.0	57000	40.0	12141000+
60.0	29930	45.0	59000	40.0	12941000+
60.0	30290	45.0	70000	35.0	10183000+

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

CONVAIR [Ref. 11:p. 29]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
See Below	N/A	1	None	0.05	0.5
Load Dir.	**Load Shape**	**Freq. (Hz)**		**Specimen**	**Finish**
Axial	Sinusoidal	5 (N<=10000) 29.2 (N>10000)		Sheet	Polished

R = - 0.5		R = - 1			
Smax (KSI)	**N**	**Smax (KSI)**	**N**	**Smax (KSI)**	**N**
80.0	700	80.0	20	45.0	43000
80.0	1080	80.0	24	42.5	35000
80.0	1090	80.0	50	42.5	39000
80.0	1550	80.0	60	42.5	43000
75.0	2670	75.0	203	42.5	43000
75.0	2710	75.0	256	40.0	30910
65.0	5000	75.0	488	40.0	32390
65.0	6000	65.0	1010	40.0	35990
65.0	9000	65.0	2000	40.0	42990
65.0	11000	65.0	2000	35.0	61240
55.0	16000	65.0	2880	35.0	73570
55.0	17480	65.0	2990	35.0	81000
55.0	20000	65.0	5000	35.0	81000
55.0	21000	55.0	8000	35.0	86850
55.0	23000	55.0	12000	35.0	89520
45.0	40000	55.0	14000	35.0	103000
45.0	41000	47.5	24000	27.5	468000
45.0	45000	47.5	24000	27.5	576000
45.0	47000	47.5	25000	27.5	702000
35.0	105000	45.0	20000	25.0	2164000
35.0	272000	45.0	22000	25.0	5829000
35.0	311000	45.0	36000	24.0	2834000
35.0	373000	45.0	37000	23.0	15439000+
35.0	1636000				
30.0	6289000				
30.0	16883000+				
30.0	18117000				

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

ALCOA [Ref. 12]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
0.1	N/A	1	None	0.1	0.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	unknown	unknown	Sheet	Smooth	

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
65.0	15600	54.0	56800	42.0	135800
65.0	16500	54.0	57200	42.0	191700
65.0	16800	54.0	59700	42.0	227700
65.0	18900	50.0	51800	40.0	106400
65.0	19400	50.0	52600	40.0	164400
65.0	20800	50.0	55200	40.0	176100
65.0	20900	50.0	61800	40.0	288500
65.0	21200	50.0	65000	40.0	540900
65.0	21800	50.0	65900	40.0	880000
65.0	22600	50.0	68500	40.0	1089500
65.0	23800	50.0	69200	40.0	1867300
65.0	25100	50.0	70200	40.0	3498800
60.0	22900	50.0	71000	40.0	5055800
60.0	25600	50.0	77300	40.0	10953200+
60.0	26000	50.0	82800	40.0	14284100
60.0	26300	48.0	92000	38.0	305200
60.0	27100	46.0	93500	38.0	327800
60.0	28300	46.0	100300	38.0	2565000
60.0	28900	46.0	123100	38.0	4756800
60.0	30100	44.0	127800	38.0	7185700
60.0	30200	44.0	128800	38.0	10748300+
60.0	34600	44.0	135500	38.0	10772900+
60.0	39800	44.0	138600	38.0	10898900+
54.0	35800	44.0	140400	38.0	12875400+
54.0	40900	44.0	143000	38.0	14457300+
54.0	42500	44.0	157500	36.0	427900
54.0	42800	44.0	164300	36.0	10929500+
54.0	43600	44.0	177900	36.0	10982500+
54.0	47700	44.0	191800	36.0	12665200+
54.0	50600	44.0	197600	36.0	12953300+
54.0	54600	44.0	253900	36.0	14314600+
54.0	54900	42.0	119700	34.0	10799300+

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 2324 [Ref. 13:p. 22,23,34]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
See Below	N/A	1	None	0.09	1
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	See Below	Sheet	Polished	

Test ratio (R) = 0.70

Smax (KSI)	N	Freq. (Hz)
80.0	2478100	18.3
75.0	10538300+	18.3

Test ratio (R) = 0.60

Smax (KSI)	N	Freq. (Hz)
80.5	224200	1.5
80.5	94500+	1.5
80.5	199700+	1.5
80.5	14500	18.3
80.5	71700	18.3
80.5	68300	18.3
80.5	99000	18.3
79.0	162100	18.3
79.0	181600	18.3
75.0	58600	18.3
70.0	432900	18.3
70.0	1140300	18.3
65.0	10780500+	18.3
60.0	10780500+	18.3

Test ratio (R) = 0.40

Smax (KSI)	N	Freq. (Hz)
80.5	22200	1.5
80.5	22600	1.5
80.5	18200	1.5
80.5	23600	1.5
80.5	23600	18.3
80.5	23200	18.3
80.5	20000	18.3
80.5	24000	18.3
78.0	27600	18.3
75.0	37500	18.3
70.0	39100	18.3
65.0	70300	1.5
65.0	63800	18.3
60.0	99200	18.3
56.0	214200	18.3
52.5	12615100+	18.3
50.0	173200	18.3
45.0	15640700+	18.3

Test ratio (R) = 0.50

Smax (KSI)	N	Freq. (Hz)
65.0	89000	18.3
62.5	4799800+	18.3

Test ratio (R) = 0.25

Smax (KSI)	N	Freq. (Hz)
70.0	29100	1.5
70.0	25100	1.5
62.5	52400	18.3
55.0	155000	1.5
55.0	157000	1.5
55.0	179000	1.5
55.0	74000	18.3
55.0	120800	18.3
50.0	3809500+	18.3

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 2324 [Ref. 13:p. 23,24,34]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
See Below	N/A	1	None	0.09	1
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	See Below	Sheet	Polished	

Test ratio (R) = 0.10		
Smax (KSI)	**N**	**Freq. (Hz)**
50.0	178000	18.3
47.5	892500	18.3

Test ratio (R) = 0.02		
Smax (KSI)	**N**	**Freq. (Hz)**
80.5	6300	1.5
80.5	5800	1.5
80.5	6100	1.5
80.5	9200	18.3
80.5	9400	18.3
80.5	9800	18.3
80.0	9700	18.3
78.0	9700	18.3
75.0	14200	1.5
75.0	16200	18.3
70.0	18800	18.3
65.0	19800	1.5
55.0	34600	1.5
50.0	48000	18.3
45.0	148900	1.5
45.0	105800	1.5
45.0	99400	18.3
45.0	160600	18.3
40.0	355600	18.3
40.0	9705800	18.3
37.5	10500000+	18.3
35.0	13785100+	18.3
30.0	10535800+	18.3

Test ratio (R) = - 0.60		
Smax (KSI)	**N**	**Freq. (Hz)**
75.0	8800	18.3
75.0	9400	18.3
75.0	11600	18.3
65.0	11000	18.3
60.0	11300	1.5
60.0	13600	1.5
60.0	15000	1.5
60.0	16500	1.5
60.0	16600	18.3
60.0	19100	18.3
60.0	19400	18.3
55.0	24600	18.3
43.0	51000	1.5
43.0	48300	1.5
43.0	63800	18.3
40.0	46100	1.5
40.0	65000	1.5
40.0	66700	1.5
40.0	152800	18.3
40.0	168700	18.3
37.5	75800	1.5
37.5	148500	1.5
37.5	254800	18.3
35.0	159300	1.5
35.0	10243000+	18.3
32.5	253600	1.5

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 2324 [Ref. 13:p. 24,28]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
See Below	See Below	1	None	0.09	1
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	18.3	Sheet	Polished	

Test ratio (R) = - 0.80		Test ratio (R) = - 1.00	
Smax (KSI)	**N**	**Smax (KSI)**	**N**
50.0	15300	50.0	13000
39.5	58100	40.0	55400
35.0	154700	40.0	66800
32.5	776300	35.0	110600
		32.5	73000
		30.0	130200
		30.0	263000
		30.0	478000
		30.0	3137000
		27.5	1205000
		25.0	9497600
		24.0	10400000+
		23.0	10133000+

Mean stress = 20.625 ksi		
Max. Stress (KSI)	**Min. Stress (KSI)**	**N**
42.00	-0.75	9418800+
42.00	-0.75	471700
43.25	-2.00	1669500+
43.25	-2.00	105400
45.00	-3.75	66600
45.00	-3.75	54700
45.00	-3.75	77400
57.50	-16.25	34900
57.50	-16.25	23200
57.50	-16.25	38000
65.00	-23.75	19300
65.00	-23.75	16800
65.00	-23.75	17900

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 3866 [Ref. 14:p. 14]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
-1	0	1	None	0.09	1
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	See Below	Sheet	Polished	

Smax (KSI)	N	Freq. (Hz)	Smax (KSI)	N	Freq. (Hz)
82.0	15	0.02	25.0	303000	30
82.0	18	0.02	25.0	324000	30
81.0	46	0.02	25.0	549000	30
80.0	50	0.02	25.0	718000	30
75.0	107	0.02	25.0	758000	30
75.0	143	0.20	20.0	573000	30
70.0	228	0.23	20.0	646000	30
70.0	320	0.22	20.0	656000	30
60.0	1667	0.33	20.0	660000	30
60.0	1688	0.27	20.0	704000	30
50.0	5182	0.32	20.0	771500	30
50.0	8132	0.33	20.0	1148000	30
50.0	18000	30	20.0	1992000	30
50.0	19000	30	20.0	41524000	30
50.0	27000	30	18.0	1049000	30
50.0	33000	30	18.0	1220000	30
50.0	36000	30	18.0	3137000	30
40.0	40000	30	18.0	3857000	30
40.0	64000	30	18.0	8956000	30
40.0	68000	30	18.0	37770000	30
40.0	104000	30	18.0	52017000+	30
30.0	95000	30	18.0	52513000+	30
30.0	147000	30	18.0	59795000	30
30.0	149000	30	18.0	97856000+	30
30.0	437000	30	17.0	1842000	30
27.0	152000	30	17.0	10856000	30
25.0	248000	30	17.0	85621000+	30
25.0	262000	30	16.5	55815000	30
25.0	295000	30			

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

CONVAIR [Ref. 11:p. 30,31]

Constant-Amplitude Data for Notched 7075-T6

					Hole (in)
					1/4 dia.
R	**Mean Stress**	**Kt**	**Notch Type**	**Thick. (in)**	**N.Width (in)**
See Below	N/A	2.6	Center Hole	0.05	1.25
Load Dir.	**Load Shape**	**Freq. (Hz)**		**Specimen**	**Finish**
Axial	Sinusoidal	5 (N<=10000) 29.2 (N>10000)		Sheet	Polished

R = 0					
Smax (KSI)	**N**	**Smax (KSI)**	**N**	**Smax (KSI)**	**N**
65.0	850	47.6	4780	20.0	54070
65.0	910	47.5	6190	20.0	66270
65.0	982	40.0	4870	20.0	65000
60.0	1240	40.0	6720	20.0	118340
60.0	1240	40.0	7310	20.0	126120
60.0	1530	40.0	7960	20.0	784900
60.0	1560	40.0	8640	20.0	1251000
55.0	2000	30.0	14780	20.0	1373500
55.0	2140	30.0	16630	20.0	1785000
55.0	2160	30.0	20235	17.5	477340
55.0	2330	30.0	23560	17.5	205050
47.5	3370	30.0	26490	15.0	4446000
47.5	4140				

R = - 0.5					
Smax (KSI)	**N**	**Smax (KSI)**	**N**	**Smax (KSI)**	**N**
73.3	73	66.6	142	60.0	276
73.3	81	66.6	152	50.0	510
73.3	84	60.0	232	50.0	675
73.3	85	60.0	236	50.0	785
66.6	135	60.0	261	50.0	835

R = - 0.75					
Smax (KSI)	**N**	**Smax (KSI)**	**N**	**Smax (KSI)**	**N**
62.8	82	62.8	87	62.8	98
62.8	83	62.8	90		

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

CONVAIR [Ref. 11:p. 32]

Constant-Amplitude Data for Notched 7075-T6

					Hole (in)
					1/4 dia.
R	**Mean Stress**	**Kt**	**Notch Type**	**Thick. (in)**	**N.Width (in)**
-1	N/A	2.6	Center Hole	0.05	1.25
Load Dir.	**Load Shape**	**Freq. (Hz)**		**Specimen**	**Finish**
Axial	Sinusoidal	5 (N<=10000) 29.2 (N>10000)		Sheet	Polished

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
55.0	71	45.0	475	25.0	13700
55.0	102	40.0	640	25.0	14365
55.0	106	40.0	650	25.0	16465
55.0	110	40.0	745	25.0	19000
50.0	150	40.0	775	25.0	21000
50.0	160	40.0	825	25.0	21710
50.0	169	35.0	1490	20.0	126000
50.0	171	35.0	1570	20.0	142000
50.0	200	35.0	1755	15.0	124000
50.0	200	35.0	1810	15.0	151000
50.0	210	35.0	2000	15.0	738000
50.0	270	30.0	5000	15.0	772000
45.0	310	30.0	5000	15.0	1640000
45.0	350	30.0	5390	15.0	2145000
45.0	370	30.0	5460	15.0	2429000
45.0	440				

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

CONVAIR [Ref. 15:p. 16; Ref. 16:p. 56]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
0	N/A	2.4	Center Hole	0.1	0.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	**Hole (in)**
Axial	Sinusoidal	29.2	Sheet	Polished	1/8 dia.

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
53.0	3015	40.0	15000	25.0	60000
53.0	3178	40.0	28000	25.0	66000
53.0	5330	40.0	30000	22.5	86000
50.0	5025	40.0	31000	22.5	94000
50.0	7000	40.0	36000	20.0	129000
50.0	8000	30.0	33000	20.0	216000
45.0	9000	30.0	36000	20.0	222000
45.0	10000	30.0	37000	17.5	946000
45.0	15000	30.0	43000	17.5	10121000
45.0	17000	25.0	46000	15.0	17619000+
40.0	14000	25.0	54000		

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 2389 [Ref. 17:p. 17,19]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
N/A	See Below	2	See Below	0.09	1.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	18.3 to 25	Sheet	Polished	

Mean stress = 0 (R = -1)					
Hole-type notch (3 in. dia.)		Edge-cut notch		Fillet-type notch	
Smax (KSI)	**N**	**Smax (KSI)**	**N**	**Smax (KSI)**	**N**
36.0	3400	34.0	5500	34.0	10000
34.0	3200	34.0	5400	34.0	11500
28.0	14000	34.0	4000	31.0	13300
24.0	42000	30.0	12000	31.0	14600
21.0	86000	30.0	11400	28.0	20000
8.0	412400	28.0	19000	24.0	39700
6.0	1028000	24.0	23700	21.0	80000
		21.0	89000	18.0	115000
		18.0	213000	5.0	4541800
		15.0	347500		
		15.0	1564300		
		12.5	10853500+		

Mean stress = 10 ksi					
Hole-type notch (3 in. dia.)		Edge-cut notch		Fillet-type notch	
Smax (KSI)	**N**	**Smax (KSI)**	**N**	**Smax (KSI)**	**N**
46.6	2600	45.0	3000	45.75	5800
46.5	2700	40.0	7000	40.00	13500
45.0	3100	35.0	18500	35.00	20500
40.0	6800	30.0	46200	30.00	59900
35.0	13000	25.0	242000	25.00	189600
30.0	22500	23.5	2678600	22.50	2998000
25.0	60700	22.5	10581900+	21.00	10336900+
22.0	227700	20.5	12653200+		
20.5	12710400+				
20.0	10547800+				

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 2389 [Ref. 17:p. 18,20]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
N/A	See Below	2	See Below	0.09	1.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	18.3 to 25	Sheet	Polished	

Mean stress = 20 ksi					
Hole-type notch (3 in. dia.)		Edge-cut notch		Fillet-type notch	
Smax (KSI)	**N**	**Smax (KSI)**	**N**	**Smax (KSI)**	**N**
56.0	2200	56.0	2100	54.0	5400
55.0	3000	55.0	3200	50.0	9000
50.0	5400	50.0	5000	45.0	17500
45.0	9300	45.0	11500	40.0	18500
40.0	12000	40.0	13400	35.0	33500
35.0	29500	35.0	28000	32.5	53000
32.0	46000	32.5	76800	30.0	105000
30.0	165600	30.0	621900	29.0	10249900+
29.0	536100	28.0	10781700+		
28.0	11250000+				

Mean stress = 30 ksi					
Hole-type notch (3 in. dia.)		Edge-cut notch		Fillet-type notch	
Smax (KSI)	**N**	**Smax (KSI)**	**N**	**Smax (KSI)**	**N**
68.0	1800	66.5	2800	65.0	4800
66.1	2400	63.0	2300	60.0	8000
65.0	2200	60.0	4100	55.0	8700
60.0	5200	55.0	8300	50.0	11500
55.0	7500	50.0	12500	45.0	27000
50.0	12000	45.0	24000	42.5	36000
45.0	24800	42.5	35000	40.0	89000
42.5	42800	39.0	81000	38.0	9978500+
39.0	198200	38.0	10062700+		
38.0	527300	37.0	10363600+		
37.0	10112300+				

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 2389 [Ref. 17:p. 21]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
N/A	See Below	4	See Below	0.09	1.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	18.3 to 25	Sheet	Polished	

Mean stress = 0			
Edge-cut notch		Fillet-type notch	
Smax (KSI)	**N**	**Smax (KSI)**	**N**
20.00	5300	22.50	8200
16.25	17800	20.00	17000
12.50	70000	16.25	63500
9.25	339200	12.50	182000
8.50	969200	10.00	4400000
7.50	1652300	7.50	10244500+
7.50	4722000		
5.50	12405300+		
4.00	10247800+		

Mean stress = 10 ksi			
Edge-cut notch		Fillet-type notch	
Smax (KSI)	**N**	**Smax (KSI)**	**N**
30.0	2000	30.0	4000
25.0	8000	27.5	10000
22.5	13000	25.0	14500
20.0	41000	22.5	45800
20.0	39000	22.5	39500
20.0	32000	20.0	140000
17.5	48500	20.0	82500
15.0	9610300	17.5	1676000
12.5	12281600+	15.0	10000000+

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 2389 [Ref. 17:p. 22]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
N/A	See Below	4	See Below	0.09	1.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	18.3 to 25	Sheet	Polished	

Mean stress = 20 ksi			
Edge-cut notch		Fillet-type notch	
Smax (KSI)	**N**	**Smax (KSI)**	**N**
35.0	2500	35.0	4000
32.5	5500	32.5	9800
30.0	10500	30.0	18700
30.0	10700	27.5	31000
27.5	16800	25.0	467000
25.0	46500	22.5	9475000+
22.5	566500		
22.5	10457000+		

Mean stress = 30 ksi			
Edge-cut notch		Fillet-type notch	
Smax (KSI)	**N**	**Smax (KSI)**	**N**
42.5	4000	45.0	3500
40.0	10000	42.5	6300
40.0	7800	40.0	12300
37.5	15000	37.5	22000
35.0	32700	35.0	119000
32.5	10744000+	32.5	10000000+

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 2390 [Ref. 18:p. 8]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
N/A	See Below	5	Edge	0.09	1.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	18.3 to 25	Sheet	Polished	

Mean stress = 0 (R = -1)		Mean stress = 10 ksi	
Smax (KSI)	**N**	**Smax (KSI)**	**N**
25.00	2000	32.0	700
22.50	3000	30.0	1700
21.00	3000	27.5	3000
20.00	4400	25.0	4700
18.00	6100	23.0	8000
15.00	15700	20.0	8500
12.00	36000	20.0	20000
10.50	83000	17.5	18000
9.00	273000	15.0	74000
8.00	500000	14.0	288000
7.50	277000	13.5	2435000
7.00	1471400	13.0	10126000+
6.50	2955900		
6.00	3500000		
5.75	7618000		
5.50	10147000+		

Mean stress = 20 ksi		Mean stress = 30 ksi	
Smax (KSI)	**N**	**Smax (KSI)**	**N**
37.5	900	47.50	900
35.0	2000	45.00	1500
32.5	3400	42.50	2700
30.0	7500	40.00	5000
27.5	11000	37.50	12000
25.0	38500	35.00	33500
24.0	75000	33.75	92500
23.0	773000	33.125	10949000+
22.5	17000000+	32.50	10516000+
22.0	10000000+		

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 2639 [Ref. 19:p. 8,9]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
N/A	See Below	1.5	Edge	0.09	1.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	18.3 to 25	Sheet	Polished	

Mean stress = 0	
Smax (KSI)	**N**
40.0	6000
39.2	13000
35.0	10000
35.0	11000
35.0	21500
32.5	26500
30.0	37700
30.0	44000
27.0	122000
25.0	95000
23.0	374000
22.0	235000
20.0	1725000
19.0	2965000
18.0	530000
18.0	8796000
17.5	2617000
17.5	4762000
17.0	5036900
16.5	16123000
16.0	6347000
15.0	14470000+

Mean stress = 10 ksi	
Smax (KSI)	**N**
44.0	23000
40.0	30000
35.0	76000
32.0	101000
28.0	472000
27.0	791000
26.0	4125000
25.0	3660000
24.0	10600000+

Mean stress = 20 ksi	
Smax (KSI)	**N**
52.0	19000
49.0	26000
46.0	33000
37.0	53000
42.0	65000
35.0	299000
34.0	217000
33.0	241000
33.0	9552000
32.0	8775000
31.0	14052000+

Mean stress = 30 ksi	
Smax (KSI)	**N**
65.0	9500
60.0	11000
60.0	16500
55.0	19000
55.0	36000
50.0	25000
50.0	54000
47.0	38000
45.0	95000
45.0	108000
44.125	57000
43.5	207000
42.5	302000
42.0	309000
41.25	96000
41.25	355800
41.0	3525000
41.0	6800000
40.0	10322000+
40.0	10630000+

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 3132 [Ref. 20:p. 8]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
-1	N/A	4	Edge	0.09	1.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	0-30	Sheet	Not Polished	

Smax (KSI)	N	Freq. (Hz)	Smax (KSI)	N	Freq. (Hz)
83.50	3	0.007	32.50	365	0.367
83.50	3	0.010	25.00	2228	0.467
82.00	4	0.008	25.00	2371	0.467
82.00	5	0.008	24.50	1588	0.533
80.00	5	0.008	20.00	5261	0.800
80.00	5	0.012	20.00	5300	18.3
70.00	10	0.012	16.25	17800	18.3
70.00	10	0.008	15.00	30000	30.0
62.50	14	0.010	12.50	70000	18.3
62.50	15	0.012	10.00	274000	30.0
62.50	17	0.012	9.25	339200	18.3
55.00	24	0.233	8.50	969200	18.3
55.00	24	0.233	8.00	10232000	30.0
47.50	50	0.017	7.50	1652300	18.3
47.50	51	0.283	7.50	4722000	18.3
40.00	85	0.317	5.50	12405300+	18.3
40.00	115	0.317	4.00	10247800+	18.3
32.50	329	0.383			

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 3631 [Ref. 21:p. 15]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
See Below	N/A	See Below	Center Hole	0.091	See Below
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	**Hole (in)**
Axial	Sawtooth	30	Sheet	Polished	See Below

Width = 4 in. ; Dia. = 1/8 in. ; Kt = 2.9					
R = 0		R = - 1			
Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
30.0	16000	25.0	9000	12.0	1475000
30.0	19000	25.0	9000	10.0	541000
25.0	39000	20.0	41000	10.0	4325000*
25.0	68000	20.0	67000	10.0	6244000
20.0	81000	18.0	81000	10.0	6725000*
20.0	107000	15.0	91000	10.0	8668000
18.0	136000	15.0	96000	9.0	22947000
18.0	300000	13.0	221000	9.0	35834000*
17.0	1783000	13.0	719000	9.0	57279000+
16.5	2404000	12.0	1054000		
16.0	33008000*				
16.0	33943000*				
16.0	51448000+				
15.0	67386000+				

Width = 4 in. ; Dia. = 1/4 in. ; Kt = 2.8			
R = 0		R = - 1	
Smax (KSI)	N	Smax (KSI)	N
30.0	17000	25.0	8000
30.0	27000	25.0	9000
25.0	41000	20.6	24000
25.0	55000	20.0	28000
20.0	168000	15.0	84000
20.0	228000	15.0	125000
18.0	15458000	12.0	314000
18.0	16786000	12.0	2769000
17.0	311000	10.0	6719000
17.0	6704000	10.0	11235000
17.0	6986000*	9.0	8614000
17.0	13042000*	9.0	20248000*
17.0	19321000*	9.0	26620000
17.0	22207000*		
17.0	35536000		

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 3631 [Ref. 21:p. 16]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
See Below	N/A	See Below	Center Hole	0.091	See Below
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	**Hole (in)**
Axial	Sawtooth	30	Sheet	Polished	See Below

Width = 4 in. ; Dia. = 2 in. ; Kt = 2.2			
R = 0		R = - 1	
Smax (KSI)	N	Smax (KSI)	N
35.0	14000	25.0	18000
35.0	16000	25.0	21000
30.0	25000	20.0	38000
30.0	64000	20.0	42000
25.0	40000	18.0	68000
25.0	82000	15.0	338000
23.0	117000	15.0	592000
23.0	140000	12.0	2929000
21.0	692000	12.0	22552000
21.0	4605000	10.0	332000
20.0	11791000	10.0	710000
20.0	51880000+	10.0	100325000+
		10.0	107947000+

Width = 2 in. ; Dia. = 1/16 in. ; Kt = 2.9			
R = 0		R = - 1	
Smax (KSI)	N	Smax (KSI)	N
35.0	15000	25.0	16000
35.0	43000	25.0	18000
30.0	32000	20.0	43000
30.0	37000	20.0	53000
25.0	66000	15.0	153000
25.0	124000	15.0	177000
23.0	107000	13.0	250000
20.0	257000	13.0	398000
20.0	2457000*	12.0	392000
20.0	7333000	12.0	3644000
20.0	7677000	11.0	8626000
19.0	22111000	11.0	19460000
18.0	30650000*	10.0	15738000
18.0	43894000	10.0	56618000

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 3631 [Ref. 21:p. 17]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
See Below	N/A	See Below	Center Hole	0.091	See Below
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	**Hole (in)**
Axial	Sawtooth	30	Sheet	Polished	See Below

Width = 2 in. ; Dia. = 1/8 in. ; Kt = 2.8					
R = 0				R = - 1	
Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
35.0	12000	19.0	175000	25.0	12000
35.0	12000	19.0	242000	25.0	13000
30.0	17000	18.0	293000	20.0	40000
30.0	46000	18.0	526000	20.0	62000
25.0	30000	18.0	17583000	15.0	85000
25.0	68000	18.0	27633000*	15.0	97000
20.0	164000	18.0	30304000+	15.0	1052000
20.0	283000	18.0	32620000*	12.0	243000
				12.0	381000
				12.0	575000
				11.0	368000
				11.0	10482000
				10.0	9109000
				10.0	45207000

Width = 2 in. ; Dia. = 1 in. ; Kt = 2.2					
R = 0				R = - 1	
Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
38.2	12000	22.0	138000	26.0	15000
35.0	13000	22.0	411000	25.0	15000
35.0	16000	21.0	434000	20.0	33000
30.0	26000	21.0	13374000	20.0	39000
30.0	26000	20.0	28164000	18.0	72000
25.0	68000	20.0	54277000+	15.0	154000
25.0	70000	20.0	90287000+	15.0	212000
23.0	63000	18.0	75512000+	14.0	2764000
23.0	287000	15.0	80746000+	14.0	2879000
23.0	5251000			13.0	10162000
				13.0	14077000
				12.0	12309000
				12.0	27850000
				11.0	78111000

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 3631 [Ref. 21:p. 18]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
See Below	N/A	See Below	Center Hole	0.091	See Below
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	**Hole (in)**
Axial	Sawtooth	30	Sheet	Polished	See Below

Width = 1/2 in. ; Dia. = 1/32 in. ; Kt = 2.8			
R = 0		R = - 1	
Smax (KSI)	N	Smax (KSI)	N
35.0	23000	30.0	11000
35.0	26000	30.0	12000
30.0	85000	25.0	21000
30.0	95000	25.0	51000
27.0	61000	20.0	182000
27.0	254000	20.0	239000
25.0	2699000	18.1	262000
25.0	5792000	15.0	543000
24.0	152000	15.0	2013000
24.0	8588000	13.0	2906000*
24.0	29000000	13.0	3543000*
23.0	145000	13.0	26767000
23.0	227000	13.0	36235000
23.0	59879000+	12.0	51922000
22.0	23393000	12.0	59056000+
20.0	54531000+		

Width = 1/2 in. ; Dia. = 1/8 in. ; Kt = 2.4			
R = 0		R = - 1	
Smax (KSI)	N	Smax (KSI)	N
35.0	21000	25.0	20000
35.0	26000	25.0	25000
30.0	38000	20.0	70000
30.0	83000	20.0	90000
25.0	144000	17.0	352000
25.0	9095000	17.0	1195000
25.0	18344000	15.0	1001000
22.0	1855000	15.0	2727000
22.0	2381000	13.0	9298000
20.0	25969000	13.0	53314000
20.0	45156000	12.0	8806000
20.0	54478000+	12.0	64530000

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 3631 [Ref. 21:p. 19]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
See Below	N/A	See Below	Center Hole	0.091	See Below
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	**Hole (in)**
Axial	Sawtooth	30	Sheet	Polished	See Below

Width = 1/2 in. ; Dia. = 1/4 in. ; Kt = 2.2			
R = 0		R = - 1	
Smax (KSI)	N	Smax (KSI)	N
35.0	23000	30.0	10000
35.0	33000	30.0	11000
30.0	57000	25.0	28000
30.0	233000	25.0	54000
25.0	1731000	20.0	84000
25.0	19810000	20.0	176000
24.0	2016000	15.0	231000
24.0	5210000	15.0	3585000
23.0	26620000	13.0	3437000
23.0	59714000	13.0	50106000
		12.0	19417000
		12.0	54651000+

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 3866 [Ref. 14:p. 15]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
-1	0	2	Edge	0.09	1.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	See Below	Sheet	See Below	

Smax (KSI)	N	Freq. (Hz)	Finish
89.0	4	0.02	Unpolished
88.0	6	0.02	Unpolished
88.0	7	0.02	Unpolished
87.0	7	0.02	Unpolished
87.0	8	0.02	Unpolished
87.0	10	0.02	Unpolished
75.0	43	0.18	Unpolished
75.0	46	0.17	Unpolished
75.0	54	0.17	Unpolished
65.0	114	0.02	Unpolished
65.0	117	0.02	Unpolished
65.0	140	0.02	Unpolished
55.0	258	0.02	Unpolished
55.0	302	0.02	Unpolished
55.0	330	0.25	Unpolished
50.0	341	0.23	Unpolished
40.0	1124	0.33	Unpolished
40.0	1313	0.33	Unpolished
40.0	1454	0.33	Unpolished
40.0	1488	0.33	Unpolished
34.0	3170	0.45	Unpolished
34.0	4000	18.3	Polished
34.0	5400	18.3	Polished
34.0	5500	18.3	Polished
30.0	6196	0.45	Unpolished
30.0	7000	30.0	Unpolished
30.0	7000	30.0	Unpolished
30.0	11400	18.3	Polished
30.0	12000	18.3	Polished
28.0	19000	18.3	Polished
24.0	23700	18.3	Polished
24.0	32000	30.0	Unpolished
23.5	31000	30.0	Unpolished
21.0	89000	18.3	Polished
18.0	213000	18.3	Polished
15.0	347500	18.3	Polished
15.0	579000	18.3	Polished
15.0	1564300	18.3	Polished
12.5	10855000+	18.3	Polished

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 3866 [Ref. 14:p. 15]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
N/A	20 ksi	2	Edge	0.09	1.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	See Below	Sheet	See Below	

Smax (KSI)	N	Freq. (Hz)	Finish
89.8	4	0.02	Unpolished
89.8	22	0.02	Unpolished
89.0	4	0.01	Unpolished
89.0	12	0.01	Unpolished
88.0	39	0.01	Unpolished
88.0	40	0.01	Unpolished
80.0	119	0.23	Unpolished
80.0	120	0.22	Unpolished
70.0	392	0.28	Unpolished
70.0	399	0.28	Unpolished
70.0	482	0.28	Unpolished
56.0	1763	0.38	Unpolished
56.0	2100	18.3	Polished
54.0	3200	18.3	Polished
50.0	4791	0.47	Unpolished
50.0	5000	18.3	Polished
45.0	6134	0.55	Unpolished
45.0	11500	18.3	Polished
40.0	13000	30.0	Unpolished
40.0	13400	18.3	Polished
35.0	28000	18.3	Polished
32.5	76800	18.3	Polished
30.0	621900	18.3	Polished
30.0	4862000	30.0	Unpolished
30.0	10546000	30.0	Unpolished
29.0	284000+	18.3	Polished
28.0	10781700+	18.3	Polished

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 3866 [Ref. 14:p. 16]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
-1	0	4	Edge	0.09	1.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	See Below	Sheet	See Below	

Smax (KSI)	N	Freq. (Hz)	Finish
83.50	3	0.01	Unpolished
83.50	3	0.01	Unpolished
82.00	4	0.01	Unpolished
82.00	5	0.01	Unpolished
80.00	5	0.01	Unpolished
80.00	5	0.01	Unpolished
70.00	10	0.01	Unpolished
70.00	10	0.01	Unpolished
62.50	14	0.01	Unpolished
62.50	15	0.01	Unpolished
62.50	17	0.01	Unpolished
55.00	24	0.23	Unpolished
55.00	24	unknown	Unpolished
47.50	50	0.02	Unpolished
47.50	51	0.28	Unpolished
40.00	85	unknown	Unpolished
40.00	115	0.32	Unpolished
32.50	329	0.38	Unpolished
32.50	365	unknown	Unpolished
30.00	2622	0.73	Unpolished
25.00	2228	0.47	Unpolished
24.50	1588	0.53	Unpolished
20.00	5261	0.80	Unpolished
20.00	5300	18.33	Polished
16.25	17800	18.33	Polished
15.00	30000	30.00	Unpolished
12.50	70000	18.33	Polished
10.00	274000	30.00	Unpolished
9.25	339200	18.33	Polished
8.50	969200	18.33	Polished
8.00	10232000	30.00	Unpolished
7.50	1652300	18.33	Polished
7.50	4722000	18.33	Polished
5.50	12405300+	18.33	Polished
4.00	10247800+	18.33	Polished

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NACA TN 3866 [Ref. 14:p. 16]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
N/A	20 ksi	4	Edge	0.09	1.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	See Below	Sheet	See Below	

Smax (KSI)	N	Freq. (Hz)	Finish
86.0	7	0.02	Unpolished
85.0	8	unknown	Unpolished
85.0	9	0.02	Unpolished
83.0	10	0.02	Unpolished
83.0	11	0.02	Unpolished
83.0	12	0.02	Unpolished
80.0	13	0.02	Unpolished
80.0	14	0.02	Unpolished
75.0	23	0.02	Unpolished
75.0	26	0.02	Unpolished
65.0	47	0.32	Unpolished
65.0	49	0.30	Unpolished
55.0	169	0.40	Unpolished
55.0	170	0.38	Unpolished
45.0	652	0.50	Unpolished
45.0	756	0.50	Unpolished
35.0	2500	18.3	Polished
35.0	3804	0.82	Unpolished
32.5	5500	18.3	Polished
30.0	2639	0.47	Unpolished
30.0	9000	30.0	Unpolished
30.0	10000	30.0	Unpolished
30.0	10500	18.3	Polished
30.0	10700	18.3	Polished
30.0	11000	30.0	Unpolished
27.5	16800	18.3	Polished
25.0	46500	18.3	Polished
25.0	85000	30.0	Unpolished
25.0	140000	30.0	Unpolished
25.0	179000	30.0	Unpolished
22.5	566500	18.3	Polished
22.5	10457000+	18.3	Polished

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NASA TN D-111 [Ref. 22:p. 10]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
N/A	See Below	4	Edge	0.09	1.5
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sawtooth	18.3 to 25	Sheet	Polished	

Notch Radius = 0.004 in.		Notch Radius = 0.070 in.	
Mean stress = 0		**Mean stress = 0**	
Smax (KSI)	**N**	**Smax (KSI)**	**N**
35.0	11000	20.0	6000
26.0	31500	15.0	26000
22.0	95000	12.5	75500
17.0	217000	10.0	257000
14.0	353000	10.0	307000
13.0	482000	8.5	275000
10.0	3375000	8.0	1920000
9.0	5045000	8.0	2690000
8.7	11299000+	7.0	5290000
8.0	14874000+	7.0	15715000+
		6.5	11878000+
		6.0	16758000+
Mean stress = 20 ksi		**Mean stress = 20 ksi**	
Smax (KSI)	**N**	**Smax (KSI)**	**N**
40.0	6300	35.0	5000
36.0	16000	31.25	9700
32.0	26000	27.5	23000
28.5	39500	26.0	35000
26.75	149000	23.75	438000
25.0	2441000	23.125	1540000
23.0	14390000+	23.0	10506000+
		22.5	16490000+

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

NASA TN D-212 [Ref. 23:p. 19]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	N.Width (in)
N/A	See Below	4	Edge	0.09	1.5
Load Dir.	**Load Shape**	**Freq. (Hz)**		**Specimen**	**Finish**
Axial	Sawtooth	30 (N>10000) <=30 (N<10000)		Sheet	Deburred

Mean stress = 0		Mean stress = 10 ksi		Mean stress = 20 ksi	
Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
50.0	40	50.0	113	50.0	363
50.0	36	50.0	92	50.0	309
40.0	136	50.0	84	30.0	13000
40.0	130	40.0	440	30.0	10800
30.0	917	40.0	374	30.0	9000
30.0	863	38.2	453	25.0	674000
30.0	654	35.0	955	25.0	335000
20.0	6000	25.0	6823	25.0	120000
20.0	6000	20.0	57820	25.0	112000
15.0	35000	20.0	32990	25.0	92000
15.0	30000	20.0	29000	25.0	81000
15.0	18000	20.0	22520	25.0	75000
12.0	149000	18.0	1106000	25.0	63000
12.0	130000	18.0	162000	25.0	42000
12.0	95000	18.0	52000	24.5	9648000
10.0	1292000	18.0	45000	24.5	5875000
10.0	673000	18.0	42000	24.5	176000
10.0	532000	17.0	2241000	24.0	44606000
10.0	456000	17.0	2102000	24.0	18575000
10.0	310000	17.0	1093000	24.0	8355000
9.0	3874000	16.0	24204000		
9.0	3309000	16.0	13877000		
9.0	2290000	16.0	8247000		
		15.0	10000000+		

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 270]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	See Below	3	Hole	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	Hole (in)
Axial	Sinusoidal	Approx. 30	Sheet	Deburred	0.601

Mean stress = - 10 ksi		Mean stress = - 5 ksi		Mean stress = 10 ksi	
Stress (KSI)	**N**	**Stress (KSI)**	**N**	**Stress (KSI)**	**N**
25	601	25	901	25	786
25	640	25	1081	25	1509
25	1425	25	1384	25	1886
25	2044	25	1642	25	2476
25	5055	25	2760	25	2621
20	2144	20	3300	20	2765
20	6200	20	3954	20	3130
20	7500	20	3960	20	4641
20	7573	20	6315	20	6264
20	11860	20	6377	20	8091
15	10800	15	10800	15	9000
15	37800	15	12600	15	10800
15	39600	15	23400	15	10800
15	43200	15	27000	15	16200
15	108000	15	41400	15	19800
10	100800	10	7200	10	27000
10	135000	10	36000	10	27540
10	203400	10	75600	10	49680
10	302400	10	270000	10	52800
10	385200	10	295560	10	55800
7.5	484200	5	374400	5	196560
7.5	525600	5	522000	5	198000
7.5	698400	5	1644500	5	198540
7.5	1674000	5	10000000+	5	201600
7.5	2719600	5	10000000+	5	239400

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 270]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	See Below	See Below	Hole(s)	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 30	Sheet	Deburred	

Kt = 3		Kt = 4		Kt = 4	
Mean stress = 15 ksi		Mean stress = - 10 ksi		Mean stress = - 5 ksi	
Stress (KSI)	**N**	**Stress (KSI)**	**N**	**Stress (KSI)**	**N**
25	660	25	1215	25	500
25	915	25	1519	25	610
25	965	25	1897	25	806
25	1072	25	2424	25	812
25	1101	25	2843	25	873
20	3272	20	1290	20	1245
20	3904	20	2445	20	1650
20	4269	20	3379	20	1886
20	4998	20	3600	20	2274
20	5200	20	5179	20	2460
15	7995	15	12600	15	3600
15	8722	15	12600	15	5400
15	10655	15	14400	15	6650
15	10707	15	16200	15	6800
15	11295	15	16200	15	7050
10	23400	12.5	13860	10	27600
10	32400	12.5	14400	10	63000
10	34200	12.5	16920	10	82800
10	43600	12.5	54600	10	86400
10	84600	12.5	79740	10	93600
5	176400	10	37440	5.5	163000
5	180000	10	91800	5.5	189000
5	232200	10	117000	5.5	1306800
5	246600	10	124200	5.5	1998000
5	460800	10	3700000	5.5	3601000

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 271]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	See Below	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 30	Sheet	Deburred	

Mean stress = 0 ksi		Mean stress = 10 ksi		Mean stress = 15 ksi	
Stress (KSI)	**N**	**Stress (KSI)**	**N**	**Stress (KSI)**	**N**
25	331	25	150	25	171
25	342	25	250	25	175
25	393	25	260	25	180
25	455	25	324	25	212
25	537	25	350	25	315
20	670	20	521	20	491
20	741	20	531	20	540
20	914	20	640	20	890
20	975	20	820	20	1030
20	1016	20	1001	20	1203
15	3600	15	1860	15	1471
15	4283	15	2500	15	2325
15	4488	15	2900	15	2600
15	6480	15	5946	15	3053
15	7200	15	6150	15	3170
10	26280	10	9000	10	6300
10	28800	10	9600	10	6450
10	29700	10	10500	10	7200
10	36180	10	12600	10	7950
10	37800	10	27000	10	15040
5	2098500	4	61200	3	90000
5	3979800	4	63000	3	174600
5	5440000	4	64800	3	370800
5	6378000	4	92800	3	406800
5	8109720	4	872000	3	2196000

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 271]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	See Below	7	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 30	Sheet	Deburred	

Mean stress = - 10 ksi		Mean stress = - 5 ksi		Mean stress = 0 ksi	
Stress (KSI)	**N**	**Stress (KSI)**	**N**	**Stress (KSI)**	**N**
20	343	25	36	20	142
20	450	25	119	20	215
20	516	25	140	20	224
20	590	25	172	20	277
20	664	25	183	20	360
15	474	20	195	15	386
15	743	20	228	15	413
15	1006	20	247	15	573
15	1200	20	293	15	636
15	1883	20	296	15	884
10	9540	15	485	10	1200
10	12600	15	672	10	1800
10	14400	15	748	10	2310
10	41400	15	753	10	3150
10	52200	15	813	10	4633
7.5	14580	10	6150	7.5	14400
7.5	40140	10	6300	7.5	16740
7.5	102780	10	7872	7.5	19800
7.5	147600	10	8100	7.5	32400
7.5	148500	10	8620	7.5	34200
5	185000	4	178200	5	51400
5	248000	4	847800	5	101500
5	390400	4	911700	5	102600
5	651600	4	1000000	5	111900
5	691700	4	10000000+	5	941600

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 272]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	See Below	See Below	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 30	Sheet	Deburred	

Kt = 7		Kt = 7		Kt = 10	
Mean stress = 10 ksi		Mean stress = 15 ksi		Mean stress = - 10 ksi	
Stress (KSI)	**N**	**Stress (KSI)**	**N**	**Stress (KSI)**	**N**
20	100	20	90	20	147
20	130	20	160	20	263
20	240	20	180	20	336
20	250	20	190	20	415
20	350	20	230	20	501
15	383	15	360	15	360
15	425	15	430	15	478
15	440	15	460	15	575
15	668	15	480	15	685
15	708	15	1033	15	3387
10	1500	10	500	10	1660
10	2450	10	900	10	2215
10	3600	10	1510	10	3215
10	4189	10	1880	10	4500
10	4950	10	2040	10	9011
5	12600	5	10800	7.5	28800
5	12600	5	12600	7.5	45000
5	14400	5	12960	7.5	66600
5	17460	5	14250	7.5	72000
5	25200	5	17280	7.5	73800
2.5	88200	2	84600	5	185400
2.5	88200	2	84600	5	352800
2.5	129600	2	185400	5	658800
2.5	691000	2	342000	5	1420200
2.5	1296000	2	10000000+	5	3216600

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 272]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	See Below	10	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 30	Sheet	Deburred	

Mean stress = - 5 ksi		Mean stress = 10 ksi		Mean stress = 15 ksi	
Stress (KSI)	**N**	**Stress (KSI)**	**N**	**Stress (KSI)**	**N**
15	450	15	156	15	125
15	450	15	168	15	184
15	562	15	177	15	199
15	753	15	179	15	202
15	1855	15	200	15	242
10	780	10	493	10	450
10	1031	10	728	10	605
10	1231	10	766	10	655
10	2331	10	794	10	761
10	3300	10	1021	10	861
7.5	916	7.5	772	5	4331
7.5	3600	7.5	1391	5	4500
7.5	4438	7.5	1462	5	4924
7.5	7200	7.5	1501	5	5400
7.5	22545	7.5	1766	5	6300
5.5	28800	5	2880	2.5	25200
5.5	36000	5	6176	2.5	28800
5.5	36000	5	6343	2.5	30600
5.5	43200	5	6999	2.5	57600
5.5	88200	5	7258	2.5	64800
4	48600	2.5	25200	1.5	340200
4	55800	2.5	36000	1.5	648000
4	144000	2.5	73440	1.5	4104900
4	824760	2.5	82620	1.5	4696200
4	888480	2.5	576000	1.5	10000000+

APPENDIX A. CONSTANT AMPLITUDE, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 273]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	See Below	See Below	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 30	Sheet	Deburred	

Kt = 4		Kt = 4		Kt = 4	
Mean stress = 1.125 ksi		Mean stress = 4.5 ksi		Mean stress = 7 ksi	
Stress (KSI)	**N**	**Stress (KSI)**	**N**	**Stress (KSI)**	**N**
4.225	10000000+	7.5	25200	15	3342
4.225	10000000+	7.5	32400	15	3465
4.225	15000000+	7.5	41400	15	3537
		7.5	43400	15	4075
		7.5	43800	15	4330
		7.5	45000		

Kt = 4		Kt = 7		Kt = 7	
Mean stress = 2.4 ksi		Mean stress = 1.125 ksi		Mean stress = 4.5 ksi	
Stress (KSI)	**N**	**Stress (KSI)**	**N**	**Stress (KSI)**	**N**
10.4	12015	4.225	144000	7.5	9900
10.4	14856	4.225	148000	7.5	10600
		4.225	364000	7.5	11900
		4.225	10000000+	7.5	13700
		4.225	10000000+	7.5	14600
		4.225	10000000+	7.5	14700

Kt = 7		Kt = 7	
Mean stress = 7 ksi		Mean stress = 2.6 ksi	
Stress (KSI)	**N**	**Stress (KSI)**	**N**
15	485	10.2	1356
15	502	10.2	1332
15	503		
15	529		
15	540		

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 355]

Spectral Data for Notched 7075-T6

LOW PEAK ORDERED GUST LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	6 ksi	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences				
2100	1393865	457862	2103148	2045688	1029604
6160	31805	10202	48008	46808	23404
10080	588	189	888	866	433
14000	5	2	8	8	4
Blocks	53.61	17.61	80.89	78.68	39.60

(Note each column contains a different specimen)

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 356]

Spectral Data for Notched 7075-T6

LOW PEAK ORDERED GUST LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	6 ksi	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences				
550	4918201	3177840	4189201	3777001	5070000
1600	2868201	1852840	2439201	2202001	2945000
2600	1474201	951840	1249201	1131001	1512000
3620	654201	421840	552001	501001	672000
4580	223701	143590	189751	170501	231000
5520	72901	46800	62101	55801	75600
6520	21466	13780	18285	16431	22260
7500	8101	5200	6901	6201	8400
8520	3241	2080	2761	2481	3360
9520	1378	884	1174	1055	1428
10500	568	364	484	435	588
11500	203	130	173	156	210
12480	81	52	69	63	84
14000	20	13	17	16	21
Blocks	81.97	52.96	69.82	62.95	84.50
	(Note each column contains a different specimen)				

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 357]

Spectral Data for Notched 7075-T6

LOW PEAK ORDERED GUST LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	6 ksi	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences				
540	4552819	5385622	5390422	10056042	5874024
1620	2652819	3135622	3140422	5856042	3424024
2590	1360819	1605622	1610422	3000042	1758024
3540	600819	705622	710422	1328042	778024
4540	203519	242022	242022	456542	264024
5540	66619	79222	79222	149442	86424
6530	19629	23342	23342	44032	25464
7540	7419	8822	8822	16642	9624
8600	2979	3542	3542	6682	3864
9660	1277	1518	1518	2864	1656
10420	537	638	638	1204	696
11000	204	242	242	457	264
12000	56	66	66	125	72
14000	19	22	22	42	25
Blocks	37.94	48.88	44.92	83.80	48.95
	(Note each column contains a different specimen)				

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 358]

Spectral Data for Notched 7075-T6

LOW PEAK RANDOM GUST LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	6 ksi	7	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences					
0	252300	169650	239250	200100	326250	213150
1190	143700	97050	136500	114100	185900	121600
2380	65900	44800	62700	52450	85500	56000
3560	23480	15980	22360	18630	30460	19940
4750	6437	4440	6157	5142	8349	5507
5950	1552	1079.5	1488	1246	2018.5	1338
7120	411.8	286.0	397.3	328.3	538.6	354.3
7720	234.4	163.6	227.2	187.6	306.2	202.0
8310	148.5	103.5	144.1	118.9	193.7	127.7
8900	90.9	62.7	88.3	72.3	119.2	77.6
9500	60.0	40.8	58.4	47.5	77.4	50.6
10000	41.8	28.4	40.8	33.3	53.7	35.3
10700	16.1	11.3	16.1	13.6	19.7	13.6
11600	10.6	7.3	10.6	9.0	12.9	9.0
11900	3.9	1.1	3.9	2.6	5.0	2.6
12050	3.6	3.6	3.6	2.5	4.6	2.5
12500	1.4		1.4	1.3	1.4	1.3
13100	1.0		1.0	1.0	1.0	1.0
	(Note each column contains a different specimen)					

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 359]

Spectral Data for Notched 7075-T6

LOW PEAK ORDERED GUST LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	6 ksi	7	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences				
550	211141	289080	305371	253531	228242
1520	104421	145280	153731	127121	113502
2370	55201	76800	80971	67201	60002
3260	25301	35200	36771	30801	27502
4190	8971	12480	12871	10921	9752
5160	2991	4160	4291	3641	3252
6170	921	1280	1321	1121	1002
7190	300	416	430	365	327
8230	139	192	199	169	152
9260	58	80	83	71	64
10380	23	32	33	29	26
11460	7	9	10	9	8
13100	2	3	3	3	3
Blocks	23.46	32.12	33.93	28.17	25.36
	(Note each column contains a different specimen)				

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 360,361]

Spectral Data for Notched 7075-T6

HIGH PEAK RANDOM GUST LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	12 ksi	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences						
0	652500	395850	456750	334950	239250	326250	247950
1000	467800	283800	327500	240300	171700	234100	177900
2000	323760	196350	226600	166250	118700	161950	123000
3000	202550	122850	141750	104050	74250	101350	76950
4000	117200	71020	82020	60220	42960	58670	44510
5000	61880	37520	43300	31800	22720	30970	23550
6000	28660	17345	20075	14710	10585	14335	10960
7000	12030	7285	8445	6180	4455	6025	4610
8000	5100	3082	3582	2615	1893	2550	1958
9000	2250	1364	1583	1157.5	833.5	1129	862
10000	1145	697	805	590.0	424.0	575	439
11000	567.3	346.2	400	292.6	210.2	285.6	217.2
12000	311.4	190.2	219.6	160.2	115.7	156.6	119.3
13000	179.7	109.5	126.4	91.9	67.1	90.0	69.0
14000	108.4	65.7	76.0	54.8	40.6	53.8	41.6
15000	39.7	22.9	27.3	18.7	15.1	18.7	15.1
16000	28.8	16.6	19.8	13.6	11.0	13.6	11.0
16190	27.3	15.7	18.7	12.8	10.4	12.8	10.4
16830	9.2	6.2	6.2	4.6	3.6	4.6	3.6
17000	4.9	3.0	3.0	1.5	1.5	1.5	1.5
18000	3.7	2.2	2.2	1.1	1.1	1.1	1.1
18290	3.4	2.0	2.0	1.0	1.0	1.0	1.0
19000	1.2						
19520	1.0						
	(Note each column contains a different specimen)						

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 362]

Spectral Data for Notched 7075-T6

HIGH PEAK ORDERED GUST LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	12 ksi	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences			
2070	304232	144578	152718	188145
6190	28000	13126	14001	17500
10350	1056	496	529	660
14200	96	46	49	60
18300	3	2	2	2
Blocks	32.89	15.63	16.51	20.34
	(Note each column contains a different specimen)			

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences			
2070	305713	207478	497650	353350
6190	28875	19250	46375	33250
10350	1089	726	1749	1254
14200	99	66	159	114
18300	3	2	5	4
Blocks	33.05	22.43	53.80	38.20
	(Note each column contains a different specimen)			

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 363]

Spectral Data for Notched 7075-T6

HIGH PEAK ORDERED GUST LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	12 ksi	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences				
480	414882	470401	813600	441281	928161
1320	284882	320401	558600	301281	638001
2220	193882	217501	380100	203281	435001
3100	108082	121801	211800	113401	243601
4020	59982	68151	117500	63451	136301
4960	30082	34801	60000	32400	69601
5900	15002	17401	30000	16201	34801
6850	6002	6961	12000	6481	13921
7860	2627	3046	5250	2836	6091
8860	1127	1306	2250	1216	2611
10100	552	639	1100	595	1277
11380	302	349	600	325	697
12350	177	204	350	190	407
13300	102	117	200	109	237
14350	52	59	100	55	117
15400	27	30	50	28	59
16550	14	15	25	14	30
17620	6	6	10	6	12
18300	3	3	5	3	6
Blocks	25.93	29.40	50.85	27.58	58.01
	(Note each column contains a different specimen)				

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 364]

Spectral Data for Notched 7075-T6

HIGH PEAK ORDERED GUST LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	12 ksi	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences				
750	319040	288960	288000	224319	256961
1980	219040	198000	198000	153999	176001
2900	149040	135000	135000	104999	120001
3920	83040	75600	75600	58799	67201
4900	46040	42300	42300	32899	37601
5830	23040	21600	21600	16799	19201
6850	11040	10800	10800	8399	9601
7880	4320	4320	4320	3359	3841
8950	1890	1890	1890	1469	1681
10000	810	810	810	629	721
11050	396	396	396	307	353
12050	216	216	216	167	193
13050	126	126	126	97	113
13700	72	72	72	55	65
14450	36	36	36	27	33
15500	18	18	18	13	17
16450	9	9	9	6	9
17500	4	4	4	2	4
18300	2	2	2	1	2
Blocks	9.97	9.03	9.00	7.01	8.03
	(Note each column contains a different specimen)				

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 365]

Spectral Data for Notched 7075-T6

HIGH PEAK RANDOM GUST LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	12 ksi	7	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences					
0	56550	95700	56550	39150	52200	52200
1670	32400	54500	32400	22600	29800	29800
3330	15000	25100	15000	10600	13700	13700
5000	5360	9000	5360	3880	4860	4860
6670	1504	2479	1504	1092	1354	1354
8330	369	606	369	267.5	329	329
10000	99.1	159.1	99.1	70.8	86.6	86.6
10830	56.8	88.9	56.8	40.5	49.6	49.6
11660	35.6	55.5	35.6	25.8	31.2	31.2
12500	21.1	33.5	21.1	15.8	18.4	18.4
13330	13.5	21.5	13.5	10.3	11.9	11.9
14000	9.2	14.7	9.2	7.2	8.2	8.2
14960	3.1	5.0	3.1	3.1	3.1	3.1
16190	2.0	3.3	2.0	2.0	2.0	2.0
16620		1.0				
	(Note each column contains a different specimen)					

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 366]

Spectral Data for Notched 7075-T6

HIGH PEAK ORDERED GUST LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	12 ksi	7	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences					
530	63002	58249	63002	68001	41253	55501
1550	43752	40249	43752	47251	28503	38501
2500	28127	25874	28127	30376	18003	24751
3450	16877	15524	16877	18226	10803	14851
4400	9627	8854	9627	10396	6163	8471
5350	4702	4323	4702	5077	3011	4137
6300	2127	1954	2127	2296	1363	1871
7400	902	827	902	973	579	793
8500	402	367	402	433	259	353
9400	117	160	177	190	115	155
10200	84	75	84	90	56	73
11150	49	43	49	52	33	42
12200	26	22	26	27	18	22
13300	16	13	16	16	11	13
14450	8	6	8	8	6	6
15500	4	3	4	4	3	3
16200	3	2	3	3	2	2
Blocks	25.19	23.29	25.19	27.24	16.52	22.23
	(Note each column contains a different specimen)					

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 373]

Spectral Data for Notched 7075-T6

ORDERED MILITARY MANEUVER LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	N/A	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	**Min. Stress**
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	5450 psi

Incremental Stress (psi)	Cumulative Frequency of Load Cycle Occurrences				
1680	12900	12898	9676	19345	15001
5180	8700	8698	6526	13045	10101
9250	5880	5878	4411	8815	6811
13550	3780	3778	2836	5665	4361
17800	2280	2278	1711	3415	2611
22100	1260	1258	946	1885	1421
26300	588	586	442	877	637
30700	240	238	181	355	260
35800	84	82	64	121	91
38450	24	22	19	34	26
42000	3	3	3	5	4
Blocks	12.00	11.99	9.00	17.99	13.95
	(Note each column contains a different specimen)				

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 372]

Spectral Data for Notched 7075-T6

RANDOM MILITARY MANEUVER LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	N/A	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	**Min. Stress**
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	5450 psi

Incremental Stress (psi)	Cumulative Frequency of Load Cycle Occurrences					
0	26400	22000	17600	30800	44000	26400
2840	20700	17250	13800	24150	34500	20700
5680	16100	13450	10760	18830	26900	16100
11400	9360	7800	6240	10920	15600	9360
17000	4560	3800	3040	5320	7600	4560
22700	1830	1525	1220	2135	3050	1830
28400	540	450	360	360	900	540
31200	288	240	192	336	480	288
34000	132	110	88	154	220	132
39800	24	20	16	28	40	24
41200	12	10	8	14	20	12
42050	6	5	4	7	10	6
	(Note each column contains a different specimen)					

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 374]

Spectral Data for Notched 7075-T6
ORDERED MILITARY MANEUVER LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	N/A	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	**Min. Stress**
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	5450 psi

Incremental Stress (psi)	Cumulative Frequency of Load Cycle Occurrences			
470	8201	17425	12298	13271
1320	7401	15725	11098	11971
2020	6801	14450	10198	10996
2730	6201	13175	9298	10021
3480	5601	11900	8398	9046
4330	5001	10625	7498	8071
5320	4521	9605	6778	7291
6420	4081	8670	6118	6576
7460	3721	7905	5578	5991
8430	3361	7140	5038	5406
9480	3001	6375	4498	4821
10560	2721	5780	4078	4366
11600	2401	5100	3598	3846
12700	2121	4505	3178	3391
13800	1881	3995	2818	3001
14900	1681	3570	2518	2676
16050	1425	3026	2134	2260
16850	1241	2635	1858	1961
17950	1081	2295	1618	1701
19400	921	1955	1378	1441
20450	769	1632	1150	1194
21500	649	1377	970	999
22800	529	1122	790	804
24000	441	935	658	661
25100	345	731	514	517
26400	281	595	418	421
27700	233	493	346	349
28800	185	391	274	277
29800	137	289	202	205
30850	105	221	154	157
32000	81	170	118	121
33150	65	136	94	97
34200	49	102	70	73
35200	37	77	52	55
36150	29	60	40	43
37150	21	43	29	31
38250	15	31	21	22
39400	10	21	14	15
40300	7	16	11	11
42000	4	9	6	6
Blocks	8.60	17.00	11.99	12.95
	(Note each column contains a different specimen)			

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 375]

Spectral Data for Notched 7075-T6

RANDOM GROUND LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	- 3 ksi	7	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences					
0	783000	500250	552450	578550	495900	448050
950	452400	289000	319300	334200	286250	258700
1920	208250	133000	146850	153800	131550	119050
2850	73600	47040	51950	54400	46450	42150
3800	20050	12846	14168	14818	12656	11460
4750	4843	3107.5	3424	3583	3057.5	2770
5700	1287	827.9	911.2	953.7	813.9	738.5
6180	715.9	461.0	507.3	530.4	453.4	410.9
6650	458.9	295.6	325.1	339.4	290.1	262.9
7130	286.2	184.3	202.6	211.6	180.3	164.3
7600	187.4	120.4	133.2	138.0	117.6	107.2
8000	129.4	83.0	91.8	94.8	80.9	73.7
8550	48.8	31.1	34.6	34.6	29.8	26.6
9250	32.8	20.8	23.1	23.1	19.8	17.8
9500	11.0	6.7	7.8	7.8	6.7	6.7
9620	10.2	6.2	7.2	7.2	6.2	6.2
9980	4.4	2.7	2.7	2.7	2.7	2.7
10450	3.4	2.0	2.0	2.0	2.0	2.0
11150	1.0					
	(Note each column contains a different specimen)					

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 376]

Spectral Data for Notched 7075-T6

ORDERED GROUND LOADING HISTORIES

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	- 3 ksi	7	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences					
550	775438	747757	1010085	1268351	900009	1309422
1580	396008	380257	516585	648851	459009	668922
2580	144008	136007	187585	235851	165009	241192
3580	41408	39107	53635	67701	47159	69012
4610	5768	5447	7370	9291	6569	9612
5700	2168	2047	2770	3491	2469	3612
6780	692	653	884	1113	788	1152
7910	296	279	378	475	337	492
8780	87	82	111	139	99	144
9480	22	20	28	34	25	36
10500	7	6	9	11	8	12
Blocks	36.07	34.78	46.98	58.99	41.86	60.90
	(Note each column contains a different specimen)					

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 377]
Spectral Data for Notched 7075-T6
ORDERED COMPOSITE LOADING HISTORIES
LOW PEAK GUST LOADINGS IN FLIGHT

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	See Below	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences				
	Gust Load				
	Mean Stress = 6000 psi				
580	674501	351000	766987	467505	1040000
1680	388501	202500	442487	269505	600000
2720	180501	94500	206487	125505	280000
3800	76501	40500	88487	53505	12000
4850	28051	14850	32437	19305	44000
5880	8161	4320	9427	5600	12800
6920	2296	1215	2647	1575	3600
7850	919	486	1054	630	1440
8700	408	216	646	280	640
9650	205	108	232	140	320
10680	82	43	93	56	128
11620	31	16	35	21	48
13000	10	5	12	7	16
	Ground Loadings				
	Mean Stress = - 3000 psi				
600	357001	189000	406232	245000	560000
1700	204001	108000	232232	140000	320000
2750	96901	51300	110432	66500	152000
3900	40801	21600	46632	28000	64000
5080	15301	8100	17632	10500	24000
6200	4591	2430	5452	3150	7200
7180	1276	675	1682	875	2000
8120	511	270	812	350	800
9020	205	108	464	140	320
9850	103	54	116	70	160
10880	52	27	58	35	80
12040	21	11	23	14	32
	Ground to Air Cycles				
	Mean Stress = 1500 psi				
4900	60486	31249	68788	411510	94287
Blocks	51.54	26.96	58.62	35.59	79.97
	(Note each column contains a different specimen)				

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 378]

Spectral Data for Notched 7075-T6

ORDERED COMPOSITE LOADING HISTORIES
LOW PEAK GUST LOADINGS IN FLIGHT

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	See Below	7	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences				
			Gust Load **Mean Stress = 6000 psi**		
650	84652	87180	52445	69305	52575
1800	48442	49950	33005	39725	33135
2750	25367	26225	15735	20875	15835
3700	9747	10165	6025	8115	6155
4650	3447	3595	2155	2895	2195
5550	1067	1113	693	923	699
6600	227	237	177	227	177
7950	105	107	61	82	61
8900	43	43	26	35	27
9550	18	18	11	15	11
11000	4	4	2	3	2
			Ground Loadings **Mean Stress = - 3000 psi**		
650	42002	43201	25811	34765	26395
1800	21702	22321	13341	17945	13635
2800	8402	8641	5171	6925	5275
3800	2522	2593	1559	2053	1585
4750	492	505	312	400	309
5720	121	123	74	98	76
6750	40	40	24	32	25
7800	15	15	9	12	9
8850	4	4	2	3	2
			Ground to Air Cycles **Mean Stress = 1500 psi**		
4650	7280	7488	4472	5928	4545
Blocks	70.54	72.61	43.57	57.93	43.98
	(Note each column contains a different specimen)				

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 379]
Spectral Data for Notched 7075-T6
ORDERED COMPOSITE LOADING HISTORIES
HIGH PEAK GUST LOADINGS IN FLIGHT

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	See Below	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences				
	Gust Load				
	Mean Stress = 12000 psi				
580	91835	120914	74142	75449	95632
1780	65435	86114	52542	53849	68032
2900	43435	57114	35002	35849	45032
3850	24735	32776	20127	20549	25876
4850	13545	17956	11027	11187	14176
5880	6665	8836	5427	5427	6976
7000	3010	3991	2452	2452	3151
8100	1247	1654	1017	1017	1306
9050	516	685	422	422	541
10080	258	343	212	212	271
11050	129	172	107	107	136
12050	69	92	58	58	73
13100	39	52	33	33	41
14200	22	29	18	18	23
15100	13	18	11	11	14
15600	6	9	6	6	7
16300	2	3	2	2	2
	Ground Loadings				
	Mean Stress = - 3000 psi				
620	44720	59281	36401	36401	46800
1680	20640	27361	16801	16801	21600
2600	8170	10831	6651	6651	8550
3650	2365	3136	1926	1926	2475
4600	430	571	351	351	450
5500	129	172	106	106	135
6450	43	58	36	36	45
7420	15	20	13	13	15
8300	4	6	4	4	4
8950	2	3	2	2	2
	Ground to Air Cycles				
	Mean Stress = 4500 psi				
7950	7955	10545	6475	6475	8325
Blocks	43.56	57.04	35.28	35.67	45.44
	(Note each column contains a different specimen)				

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 380,381]
Spectral Data for Notched 7075-T6
ORDERED COMPOSITE LOADING HISTORIES
HIGH PEAK GUST LOADINGS IN FLIGHT

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	See Below	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences			
	Gust Load			
	Mean Stress = 12000 psi			
550	179556	231785	302418	197951
1700	129556	166785	217418	142951
2650	79556	101785	132418	87951
3450	47556	60185	79201	52751
4350	25556	32503	42901	28551
5320	13556	17503	23131	15351
6420	5702	7503	9901	6551
7500	2377	3128	4126	2701
8500	952	1253	1651	1051
9600	477	623	826	526
10620	230	303	397	253
11580	135	178	232	148
12580	68	90	116	74
13520	39	52	66	42
14450	20	27	33	21
15450	10	14	16	10
16420	4	6	6	4
18300	2	3	3	2
	Ground Loadings			
	Mean Stress = - 3000 psi			
550	19002	25013	33004	21004
1520	10452	13763	18154	11554
2550	3612	4763	6274	3994
3520	1142	1513	1984	1264
4500	230	313	400	256
5520	68	88	119	77
6520	22	28	36	24
7520	10	13	16	11
9300	2	3	3	2
	Ground to Air Cycles			
	Mean Stress = 4500 psi			
7850	1748	2300	3036	1932
Blocks	19.85	25.67	33.54	21.89
	(Note each column contains a different specimen)			

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 380,381]
Spectral Data for Notched 7075-T6
ORDERED COMPOSITE LOADING HISTORIES
HIGH PEAK GUST LOADINGS IN FLIGHT

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	See Below	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Varying Stress (psi)	Cumulative Frequency of Load Cycle Occurrences			
	Gust Load			
	Mean Stress = 12000 psi			
550	246129	240364	158896	269287
1700	176129	172864	113896	194287
2650	108002	107864	68896	119287
3450	64802	64664	40803	71287
4350	35102	34964	22103	38287
5320	13902	18764	11903	20302
6420	8102	7964	5103	8702
7500	3377	3251	2128	3627
8500	1352	1301	853	1452
9600	667	651	428	727
10620	326	313	207	350
11580	191	183	122	205
12580	96	92	62	103
13520	55	53	36	59
14450	28	27	19	30
15450	14	14	10	15
16420	6	6	4	6
18300	3	3	2	3
	Ground Loadings			
	Mean Stress = - 3000 psi			
550	27004	26004	17004	29005
1520	14854	14304	9354	15955
2550	5134	4944	3234	5515
3520	1624	1564	1024	1745
4500	328	316	208	353
5520	98	95	63	106
6520	30	30	20	3
7520	14	14	9	15
9300	3	3	2	3
	Ground to Air Cycles			
	Mean Stress = 4500 psi			
7850	2484	2392	1564	2668
Blocks	27.31	26.63	17.58	29.82
	(Note each column contains a different specimen)			

APPENDIX B. SPECTRAL, AXIAL FATIGUE

LOCKHEED [Ref. 24:p. 382]
Spectral Data for Notched 7075-T6
RANDOM COMPOSITE LOADING HISTORIES
MILITARY MANEUVER LOADINGS IN FLIGHT

R	Mean Stress	Kt	Notch Type	Thick. (in)	Width (in)
N/A	See Below	4	Holes	0.04	3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**	
Axial	Sinusoidal	Approx. 60	Sheet	Deburred	

Dynamic Stress (psi)	Cumulative Frequency of Load Cycle Occurrences				
			Military Maneuver Loadings		
(Incremental)			**Minimum Stress = 5450 psi**		
0	7236	8126	9549	7711	10676
2840	5674	6371	7488	6046	8371
5680	4424	4968	5838	4714	6527
11400	2566	2881	3386	2734	3785
17000	1250	1404	1649	1332	1844
22700	502	563	662	534	740
28400	148	166	195	158	218
31200	78	88	104	84.1	116
34000	36.2	40.6	47.7	38.6	53.4
39700	6.58	7.39	8.68	7.01	9.71
41200	3.29	3.69	4.34	3.50	4.85
42000	1.64	1.85	2.17	1.75	2.43
			Ground Loadings		
(Varying)			**Mean Stress = - 3000 psi**		
0	1682	1888	2216	1793	2478
950	971	1090	1280	1036	1431
1920	446	501	588	476	658
2850	158	177	208	168	233
3800	43.0	48.2	56.6	45.8	63.3
4750	10.4	11.6	13.7	11.1	15.3
5700	2.75	3.09	3.63	2.94	4.06
6180	1.53	1.72	2.02	1.63	2.26
6650	0.982	1.10	1.29	1.05	1.45
7130	0.61	0.69	0.81	0.65	0.90
7600	0.41	0.45	0.53	0.43	0.59
8000	0.28	0.31	0.36	0.29	0.41
8550	0.10	0.12	0.14	0.11	0.15
9250	0.070	0.078	0.092	0.074	0.100
9500	0.024	0.026	0.031	0.025	0.035
9620	0.022	0.024	0.029	0.023	0.032
9980	0.008	0.009	0.011	0.009	0.012
10450	0.006	0.007	0.008	0.006	0.009
			Ground-Air-Ground Loading		
			Mean Stress = 1225 psi		
4225	240	270	317	256	354
	(Note each column contains a different specimen)				

APPENDIX C. CONSTANT AMPLITUDE, ROTATIONAL FATIGUE

NASA TN D-210 [Ref. 25:p. 14]

Constant-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Dia. (in)
-1	0	1	None	0.3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**
Rotational	Sinusoidal	133.3	Extruded Rod	Polished

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
45.0	369000	32.0	319000	25.0	57408000
45.0	209000	28.0	42229000	25.0	27358000
45.0	190000	28.0	26681000	25.0	25108000
45.0	186000	28.0	18223000	25.0	16089000
45.0	134000	28.0	7449000	25.0	2590000
45.0	105000	28.0	6902000	24.0	517318000+
45.0	103000	28.0	3005000	24.0	510055000+
45.0	76000	28.0	1876000	24.0	506378000+
45.0	75000	28.0	1738000	24.0	504590000+
36.0	929000	28.0	979000	24.0	104613000
36.0	763000	28.0	902000	24.0	8161000
36.0	430000	26.0	549810000+	24.0	4090000
36.0	401000	26.0	278328000	24.0	3456000
36.0	314000	26.0	222182000	24.0	2408000
36.0	298000	26.0	135577000	24.0	2310000
36.0	266000	26.0	122367000	23.0	863224000+
36.0	219000	26.0	65317000	23.0	590857000+
36.0	208000	26.0	40055000	23.0	547322000+
36.0	179000	26.0	38539000	23.0	544945000+
32.0	3844000	26.0	11419000	23.0	530763000+
32.0	2993000	26.0	1004000	23.0	516099000+
32.0	776000	25.0	509037000+	23.0	505082000+
32.0	776000	25.0	291754000	23.0	205282000
32.0	665000	25.0	243666000	23.0	137207000
32.0	665000	25.0	186662000	22.0	995264000+
32.0	600000	25.0	85167000	22.0	764156000+
32.0	504000	25.0	63380000	22.0	380494000+
32.0	374000				

APPENDIX C. CONSTANT AMPLITUDE, ROTATIONAL FATIGUE

NASA TN D-210 [Ref. 25:p. 15]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Net Dia. (in)
-1	0	1.38	0.094-in. radius	0.3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**
Rotational	Sinusoidal	133.3	Extruded Rod	Polished

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
36.0	3318000	28.0	22918000	22.0	150412000
36.0	282000	28.0	12838000	22.0	118263000
36.0	144000	28.0	4694000	22.0	107573000
36.0	142000	28.0	4611000	22.0	88493000
36.0	108000	28.0	1515000	22.0	61015000
36.0	86000	28.0	1388000	22.0	60528000
36.0	81000	28.0	967000	22.0	18389000
36.0	80000	28.0	766000	22.0	7020000
36.0	76000	28.0	375000	22.0	2571000
36.0	70000	28.0	340000	20.0	658449000+
32.0	11600000	25.0	32273000	20.0	599517000
32.0	721000	25.0	27558000	20.0	592748000+
32.0	349000	25.0	23875000	20.0	512303000+
32.0	296000	25.0	19132000	20.0	501931000+
32.0	229000	25.0	18995000	20.0	309694000
32.0	207000	25.0	15223000	20.0	278180000
32.0	131000	25.0	12560000	20.0	29402000
32.0	131000	25.0	11924000	20.0	9888000
32.0	94000	25.0	11785000		
32.0	82000	25.0	11348000		

APPENDIX C. CONSTANT AMPLITUDE, ROTATIONAL FATIGUE

NASA TN D-210 [Ref. 25:p. 16]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Net Dia. (in)
-1	0	3	0.010-in. radius	0.3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**
Rotational	Sinusoidal	133.3	Extruded Rod	Polished

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
36.0	9900	18.0	642000	12.0	2429000
36.0	9600	18.0	592000	12.0	1772000
36.0	9400	18.0	480000	12.0	1296000
36.0	9000	18.0	446000	12.0	1289000
36.0	8700	18.0	205000	11.0	268102000
36.0	8400	18.0	171000	11.0	240710000
36.0	8000	18.0	121000	11.0	108446000
36.0	7800	16.0	763000	11.0	63237000
36.0	7400	16.0	739000	11.0	49208000
36.0	7100	16.0	722000	11.0	48090000
30.0	19200	16.0	643000	11.0	11440000
30.0	17700	16.0	423000	11.0	4938000
30.0	17600	16.0	405000	11.0	1380000
30.0	17100	16.0	303000	10.0	515286000+
30.0	16400	16.0	210000	10.0	488868000
30.0	16300	16.0	182000	10.0	486409000
30.0	16100	16.0	41000	10.0	432442000
30.0	16000	13.0	6274000	10.0	364450000
30.0	15900	13.0	3732000	10.0	354455000
30.0	15400	13.0	2422000	10.0	240908000
22.0	269000	13.0	2212000	10.0	118135000
22.0	67000	13.0	1880000	10.0	108395000
22.0	63000	13.0	1565000	10.0	11703000
22.0	59000	13.0	1552000	9.0	1181557000+
22.0	57000	13.0	1122000	9.0	827652000+
22.0	52000	13.0	1107000	9.0	733298000+
22.0	51000	13.0	1051000	9.0	698649000+
22.0	46000	12.0	71645000	9.0	529500000+
22.0	44000	12.0	13434000	9.0	509324000+
22.0	40000	12.0	12840000	9.0	504416000+
18.0	18499000	12.0	9625000	9.0	501046000+
18.0	1916000	12.0	3074000	9.0	500128000+
18.0	877000	12.0	3033000		

APPENDIX C. CONSTANT AMPLITUDE, ROTATIONAL FATIGUE

NASA TN D-210 [Ref. 25:p. 17]

Constant-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Net Dia. (in)
-1	0	5	0.0032-in. radius	0.3
Load Dir.	**Load Shape**	**Freq. (Hz)**	**Specimen**	**Finish**
Rotational	Sinusoidal	133.3	Extruded Rod	Polished

Smax (KSI)	N	Smax (KSI)	N	Smax (KSI)	N
22.0	41000	13.0	263000	8.0	5439000
22.0	36000	13.0	253000	8.0	2845000
22.0	36000	13.0	224000	8.0	2249000
22.0	36000	10.0	1388000	8.0	2045000
22.0	33000	10.0	1383000	8.0	1668000
22.0	29000	10.0	1276000	8.0	1658000
22.0	28000	10.0	1156000	7.5	787812000+
22.0	20000	10.0	1020000	7.5	515239000+
22.0	17000	10.0	984000	7.5	504823000+
22.0	17000	10.0	867000	7.5	503136000+
18.0	689000	10.0	846000	7.5	122585000
18.0	445000	10.0	840000	7.5	17774000
18.0	399000	10.0	799000	7.5	13089000
18.0	71000	9.0	2449000	7.5	11485000
18.0	52000	9.0	1766000	7.5	3682000
18.0	47000	9.0	1490000	7.5	3611000
18.0	44000	9.0	1479000	7.0	1125295000+
18.0	36000	9.0	1445000	7.0	715839000+
18.0	31000	9.0	1439000	7.0	616445000+
18.0	29000	9.0	1430000	7.0	505327000
13.0	842000	9.0	1132000	7.0	267124000
13.0	782000	9.0	1116000	7.0	197869000
13.0	708000	9.0	735000	7.0	34984000
13.0	690000	8.0	1158980000+	7.0	5764000
13.0	641000	8.0	33530000	7.0	2965000
13.0	423000	8.0	32072000	7.0	2758000
13.0	328000	8.0	8755000		

APPENDIX D. SPECTRAL, ROTATIONAL FATIGUE

NASA TN D-210 [Ref. 25:p. 18,19]

Varying-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Dia. (in)	
-1	0	1	None	0.3	
Load Dir.	**Load Shape**		**Freq. (Hz)**	**Specimen**	**Finish**
Rotational	Sinusoidal Modulation		133.3	Extruded Rod	Polished

Smax (KSI)	Smin (KSI)	N	Smax (KSI)	Smin (KSI)	N
35.0	16.4	3643000	28.0	9.1	96170000
35.0	15.4	1809000	28.0	9.0	90444000
35.0	14.8	1748000	35.0	22.8	21925000
35.0	15.7	1249000	35.0	22.4	20594000
35.0	15.8	1160000	35.0	22.6	4944000
35.0	15.8	1034000	35.0	22.0	3821000
35.0	16.2	1021000	35.0	22.7	1866000
35.0	15.9	888000	30.0	17.9	94420000
35.0	15.0	803000	30.0	17.4	58277000
35.0	15.1	491000	30.0	18.0	51282000
35.0	15.8	490000	30.0	17.8	1433000
32.0	12.8	34908000	30.0	18.0	540000
32.0	12.5	22652000	35.0	28.2	1293000
32.0	12.1	8070000	35.0	28.3	606000
32.0	12.5	4632000	35.0	28.4	574000
32.0	12.4	2430000	35.0	28.2	520000
31.0	11.8	10121000	32.0	25.3	2778000
31.0	11.9	3410000	32.0	25.2	2718000
31.0	10.6	1525000	32.0	25.1	1033000
31.0	11.1	1194000	32.0	25.1	1000000
30.0	10.0	405467000+	32.0	25.2	529000
30.0	11.2	64256000	28.0	21.3	193961000
30.0	10.2	45500000	28.0	21.4	78816000
30.0	10.7	3058000	28.0	21.3	10640000
29.0	8.7	2230000	28.0	21.3	3065000
30.0	10.0	1364000	28.0	21.1	3060000
30.0	9.5	1265000			

APPENDIX D. SPECTRAL, ROTATIONAL FATIGUE

NASA TN D-210 [Ref. 25:p. 20]

Varying-Amplitude Data for Unnotched 7075-T6

R	Mean Stress	Kt	Notch Type	Dia. (in)	
-1	0	1	None	0.3	
Load Dir.	**Load Shape**		**Freq. (Hz)**	**Specimen**	**Finish**
Rotational	Exponential Modulation		133.3	Extruded Rod	Polished

Smax (KSI)	Smin (KSI)	N
35.0	16.4	6240000
35.0	16.6	5180000
35.0	16.0	2470000
32.0	14.1	202210000
32.0	13.5	175183000
32.0	13.1	12780000
32.0	13.4	4591000
32.0	13.5	2909000
35.0	22.5	3370000
35.0	22.7	2501000
35.0	22.6	1773000
35.0	22.2	1325000
32.0	19.3	108882000
32.0	19.1	61080000
30.0	17.9	258006000
30.0	17.2	237102000
30.0	18.8	116334000
30.0	17.7	10493000
30.0	17.6	9341000
30.0	17.1	2687000
35.0	29.0	2015000
35.0	28.9	1202000
35.0	29.0	1113000
30.0	24.2	219102000
30.0	23.8	4291000
30.0	24.1	666000
28.0	22.1	146551000
28.0	21.7	28194000
28.0	22.1	25138000

APPENDIX D. SPECTRAL, ROTATIONAL FATIGUE

NASA TN D-210 [Ref. 25:p. 21]

Varying-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Net Dia. (in)	
-1	0	3	0.010-in. radius	0.3	
Load Dir.	**Load Shape**		**Freq. (Hz)**	**Specimen**	**Finish**
Rotational	Sinusoidal Modulation		133.3	Extruded Rod	Polished

Smax (KSI)	Smin (KSI)	N	Smax (KSI)	Smin (KSI)	N
25.0	4.4	130000	18.0	4.8	594000
25.0	4.6	110000	18.0	5.0	483000
25.0	4.2	110000	18.0	4.9	397000
25.0	4.3	109000	18.0	4.6	304000
25.0	4.8	105000	20.0	12.8	100000
25.0	4.5	100000	20.0	12.7	100000
25.0	4.3	91000	20.0	12.9	92000
25.0	4.3	81000	20.0	12.8	74000
25.0	3.9	79000	16.0	8.7	609000
20.0	1.1	1579000	16.0	8.9	548000
20.0	1.6	1452000	16.0	9.0	497000
20.0	1.4	921000	16.0	9.0	331000
20.0	2.3	412000	16.0	8.7	262000
20.0	1.6	370000	12.0	4.8	21681000
20.0	0.8	334000	12.0	4.8	17741000
20.0	2.1	234000	12.0	4.8	3733000
20.0	1.0	202000	12.0	4.9	1200000
20.0	0.5	68000	11.0	3.8	394512000
20.0	6.4	346000	11.0	3.8	74000000
20.0	6.6	293000	11.0	3.7	47911000
20.0	6.6	271000	11.0	3.9	29279000
20.0	6.5	271000	11.0	3.8	29101000
18.0	4.6	667000			

APPENDIX D. SPECTRAL, ROTATIONAL FATIGUE

NASA TN D-210 [Ref. 25:p. 22]

Varying-Amplitude Data for Notched 7075-T6

R	Mean Stress	Kt	Notch Type	Net Dia. (in)	
-1	0	3	0.010-in. radius	0.3	
Load Dir.	**Load Shape**		**Freq. (Hz)**	**Specimen**	**Finish**
Rotational	Exponential Modulation		133.3	Extruded Rod	Polished

Smax (KSI)	Smin (KSI)	N
20.0	1.90	3371000
20.0	0.90	1780000
20.0	0.38	1410000
20.0	6.90	1050000
20.0	7.00	990000
20.0	6.60	978000
20.0	6.80	549000
18.0	4.60	2030000
18.0	5.00	1993000
18.0	5.40	1204000
17.0	3.70	5494000
17.0	5.90	4990000
17.0	5.90	4480000
16.0	9.50	2347000
16.0	9.20	1711000
16.0	9.30	1316000
16.0	9.20	879000
16.0	9.30	100000
14.0	7.40	38000000
14.0	7.70	33443000
14.0	7.20	6933000
14.0	7.30	4834000
14.0	7.30	2527000
12.0	5.40	337566000
12.0	5.50	255588000
12.0	5.30	155059000
12.0	5.30	44868000
12.0	5.30	42600000

APPENDIX D. SPECTRAL, ROTATIONAL FATIGUE

NASA TN D-210 [Ref. 25:p. 23]

Varying-Amplitude Data for Notched 7075-T6

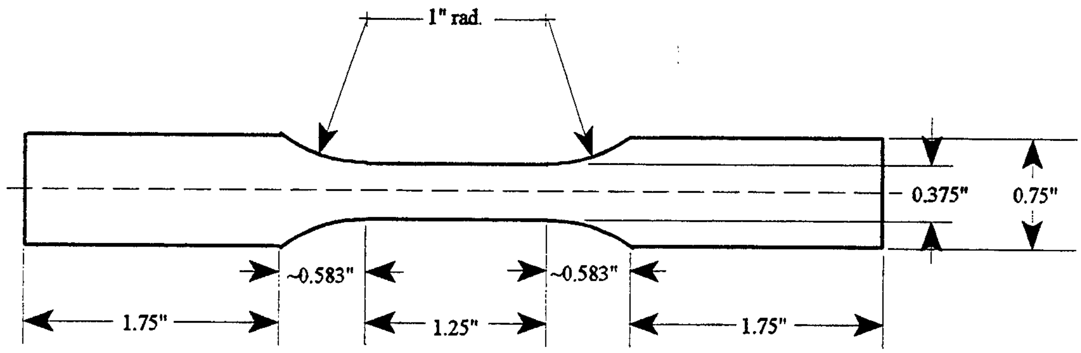
R	Mean Stress	Kt	Notch Type	Net Dia. (in)	
-1	0	3	0.010-in. radius	0.3	
Load Dir.	**Load Shape**		**Freq. (Hz)**	**Specimen**	**Finish**
Rotational	Gust Frequency Spectrum		133.3	Extruded Rod	Polished

Smin = 2 ksi; Smax = 34 ksi DeltaS/10,000rev = 8 ksi;	Smin = 10 ksi; Smax = 34 ksi DeltaS/10,000rev = 8 ksi;
N	**N**
2450000	280115
2328710	247900
2116700	247060
2019440	225530
2004547	222150
1988780	220280
1906420	214060
1893000	208560
1789600	203860
1781236	200740
1773000	198250
1675620	213300
1668837	181135
1554400	175500
	168620

Smin = 9 ksi; Smax = 29 ksi DeltaS/1,000rev = 5 ksi;
N
1438740
1337930
1326330
1110100
1109730
1106390
968290
865880
743350

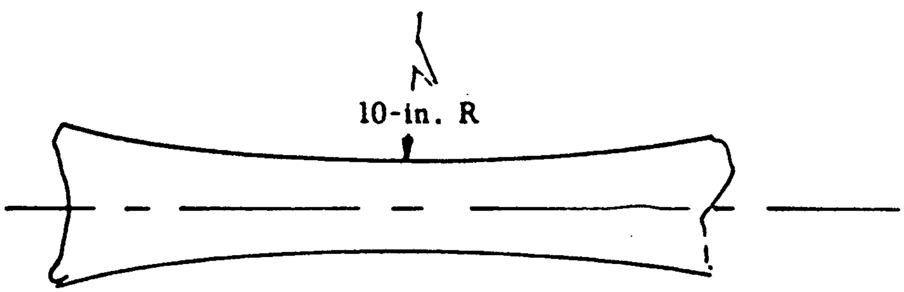
APPENDIX E. SPECIMEN DRAWINGS

NPS [Kousky, 1997 & Smith, 1993]



APPENDIX E. SPECIMEN DRAWINGS

CONVAIR [Ref. 10:p. 5]

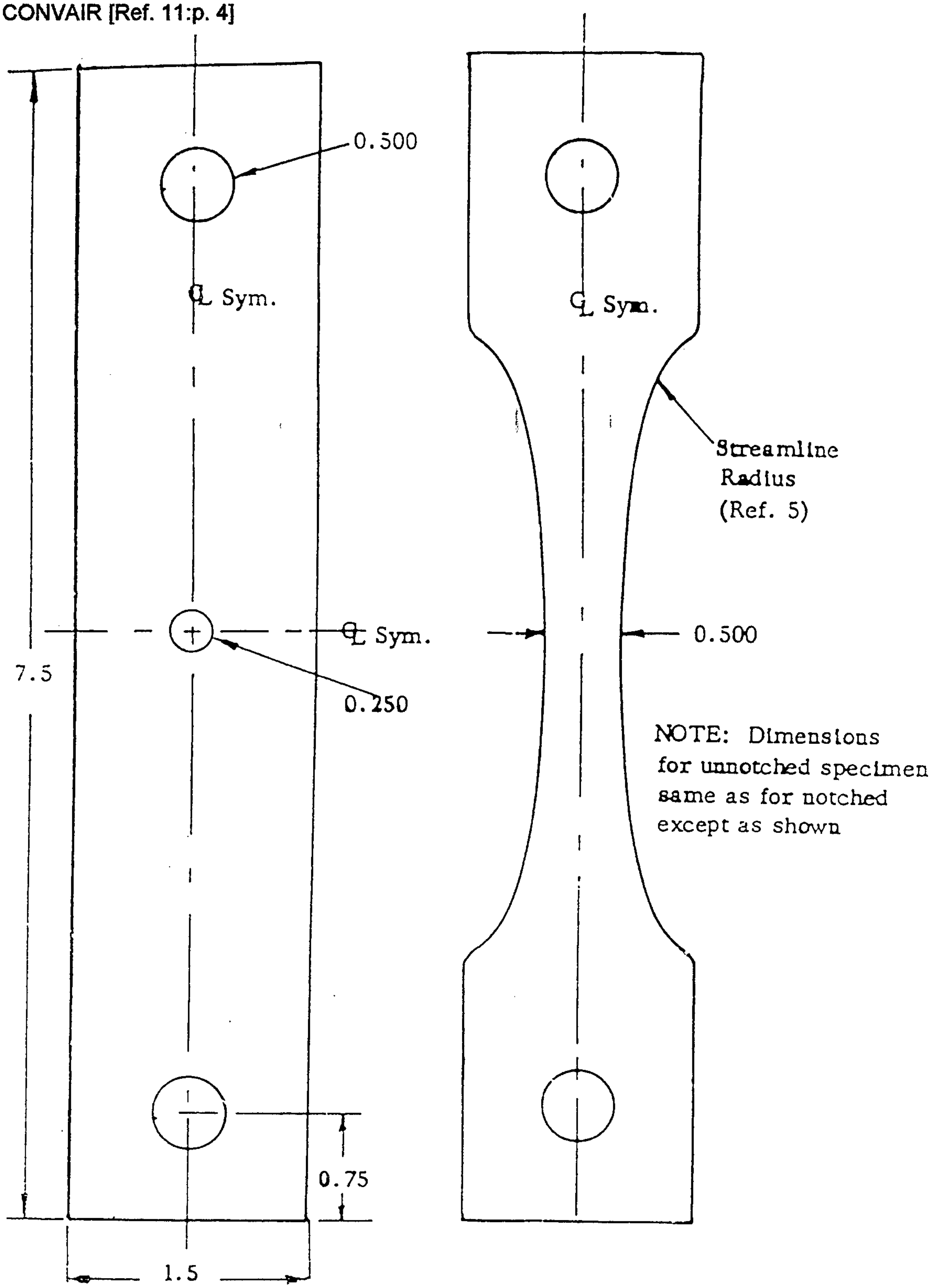


Unnotched Specimen

All specimens were made of 0.1-inch-thick 7075-T6 aluminum alloy having a width of 1 inch at the test section.

APPENDIX E. SPECIMEN DRAWINGS

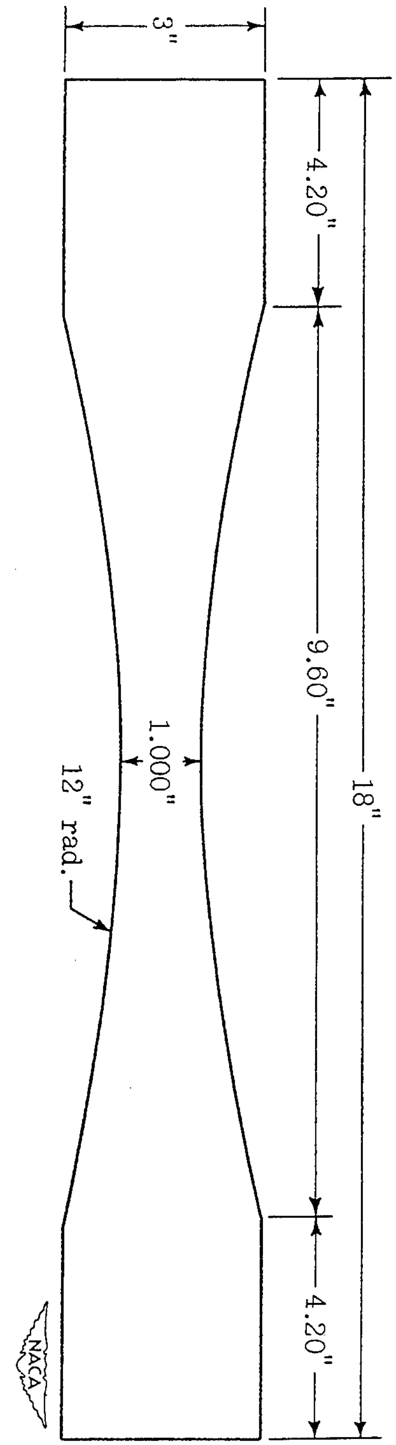
CONVAIR [Ref. 11:p. 4]



(a) Notched (K_t = 2.57)[5] (b) Unnotched

APPENDIX E. SPECIMEN DRAWINGS

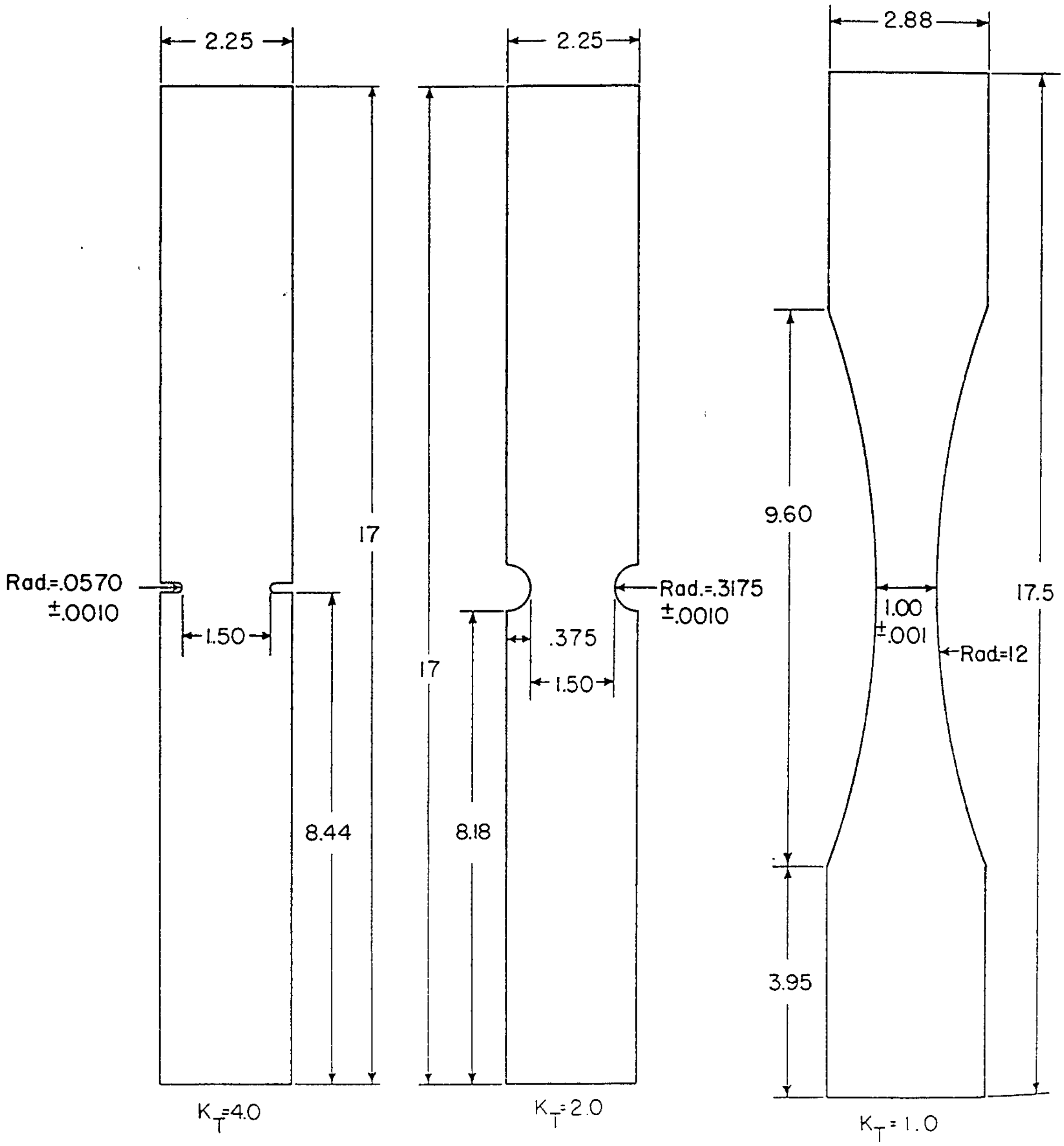
NACA TN 2324 [Ref. 13:p. 42]



Fatigue test specimen.

APPENDIX E. SPECIMEN DRAWINGS

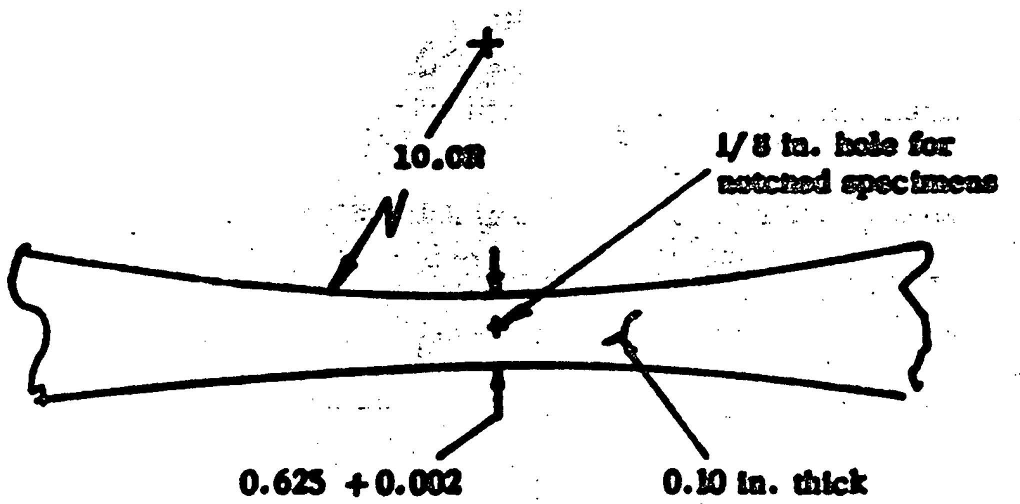
NACA TN 3866 [Ref. 14:p. 24]



Configurations of sheet specimens. Aluminum specimens, 0.090 inch thick;

APPENDIX E. SPECIMEN DRAWINGS

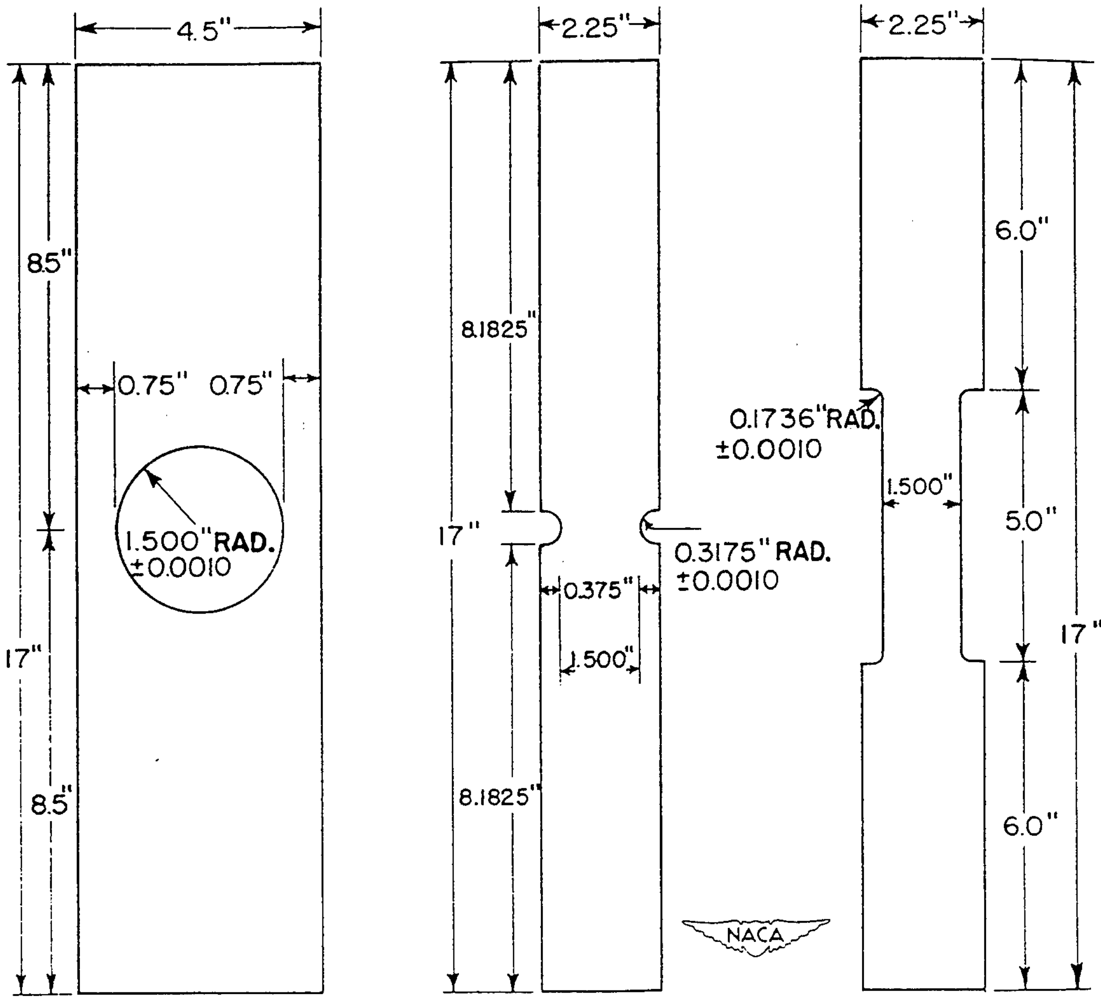
CONVAIR [Ref. 15:p. 20]



Unnotched and center-hole ($K_t = 2.4$)

APPENDIX E. SPECIMEN DRAWINGS

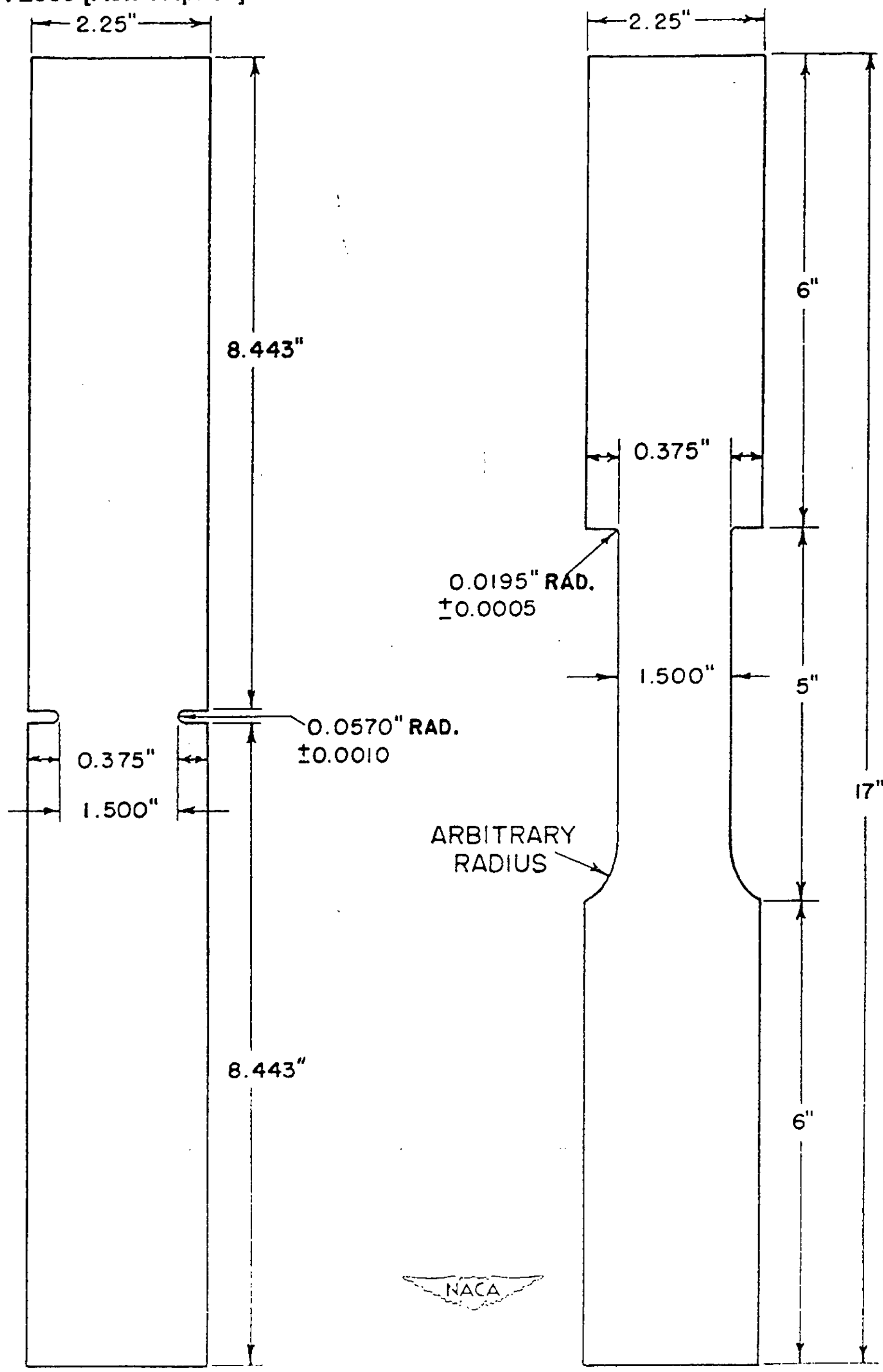
NACA TN 2389 [Ref. 17:p. 36]



(a) Hole-type notch. (b) Edge-cut notch. (c) Fillet-type notch.

Notched fatigue test specimens with $K_t = 2.0$.

NACA TN 2389 [Ref. 17:p. 37]

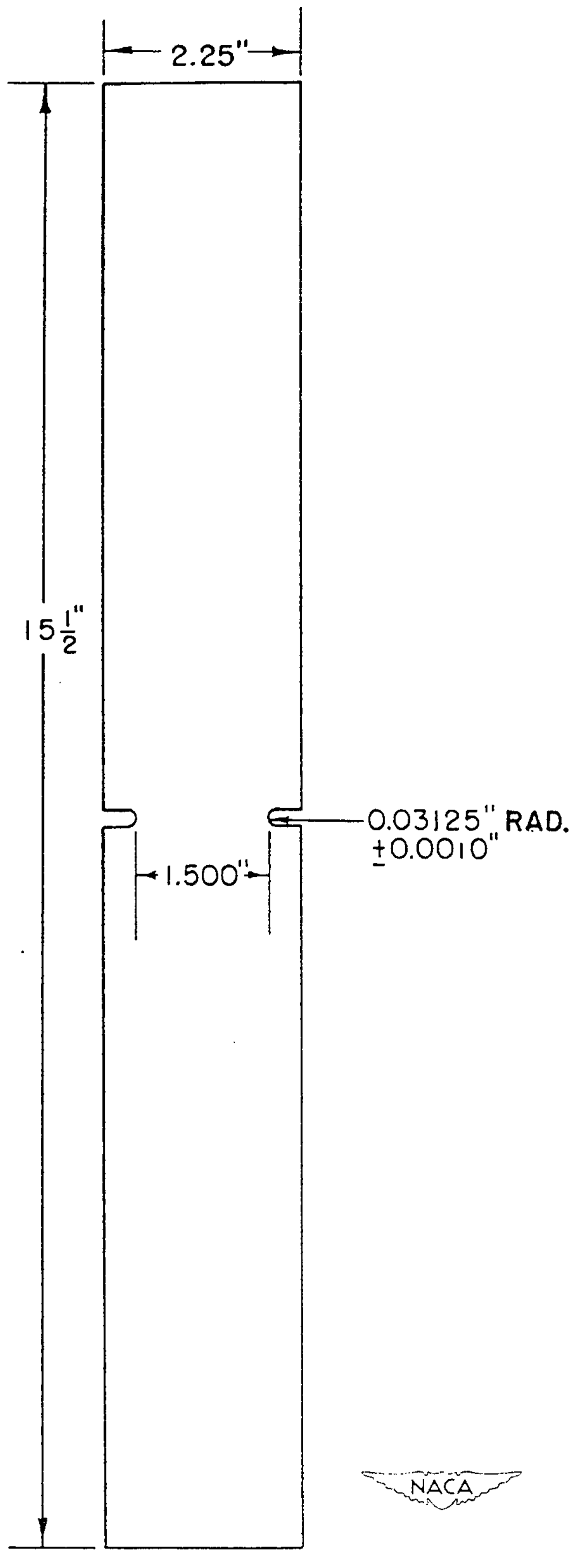


(a) Edge-cut notch. (b) Fillet-type notch.

Notched fatigue test specimens with $K_t = 4.0$.

APPENDIX E. SPECIMEN DRAWINGS

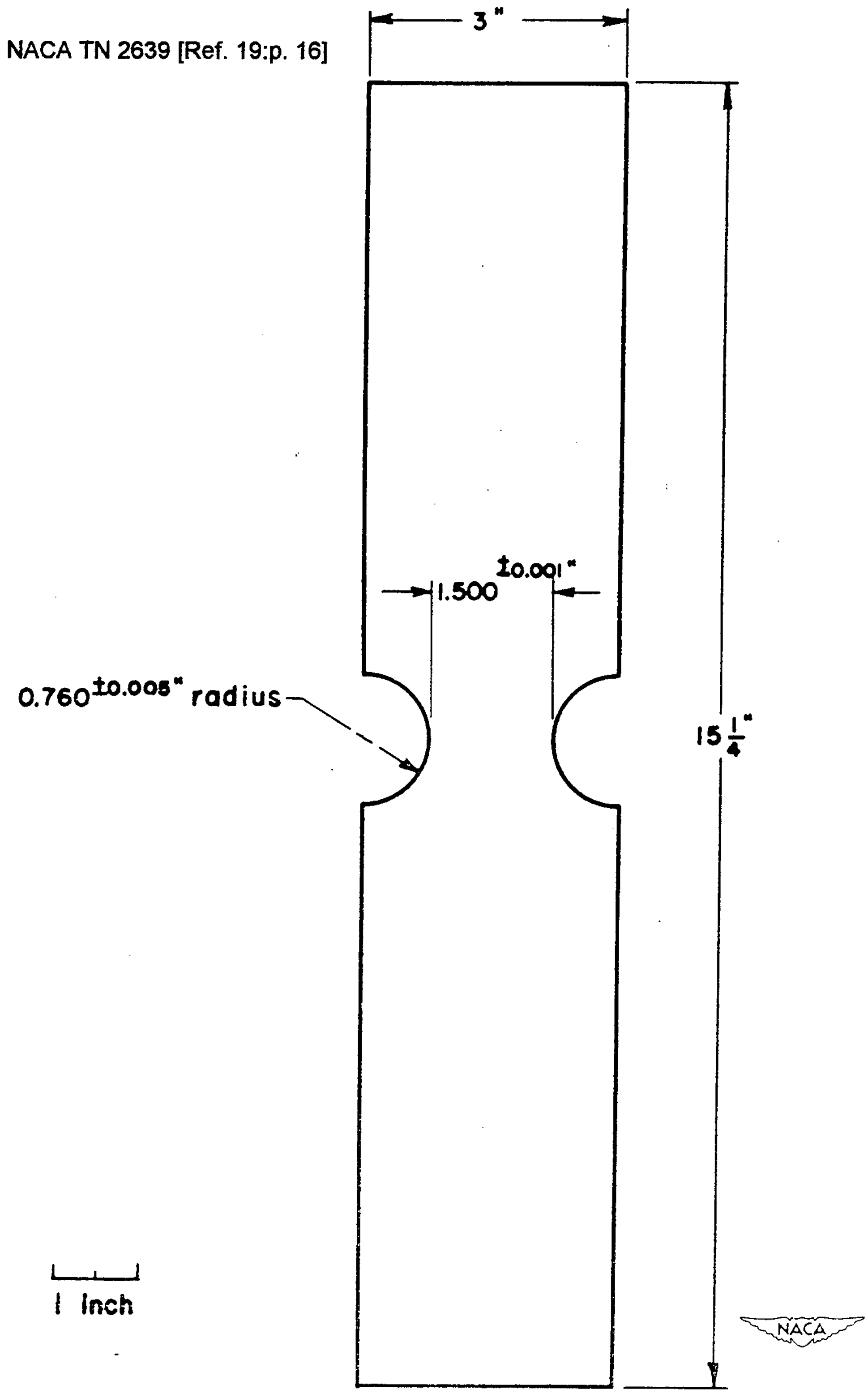
NACA TN 2390 [Ref. 18:p. 14]



Notched fatigue test specimen with $K_t = 5$.

APPENDIX E. SPECIMEN DRAWINGS

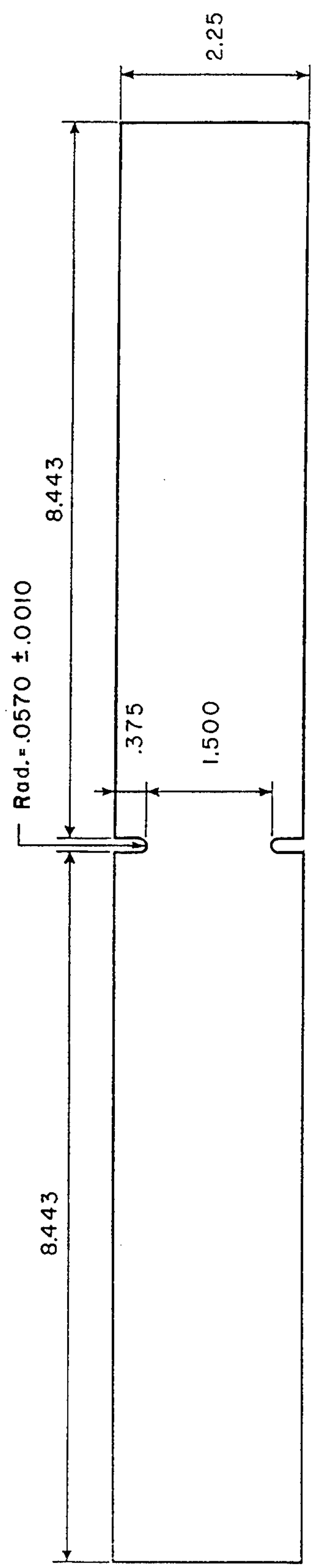
NACA TN 2639 [Ref. 19:p. 16]



Notched fatigue test specimen with $K_t = 1.5$.

APPENDIX E. SPECIMEN DRAWINGS

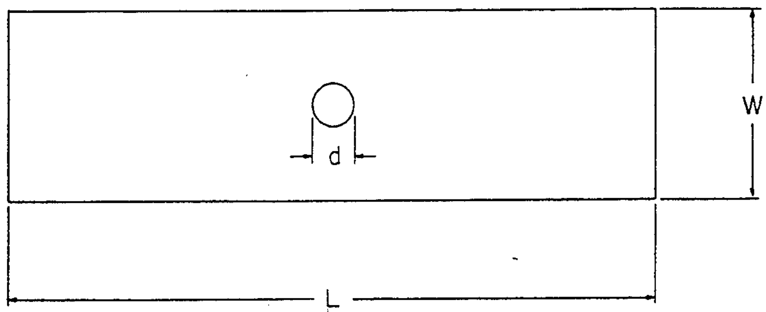
NACA TN 3132 [Ref. 20:p. 9]



Notched fatigue test specimen with $K_T = 4.0$.

APPENDIX E. SPECIMEN DRAWINGS

NACA TN 3631 [Ref. 21:p. 22]

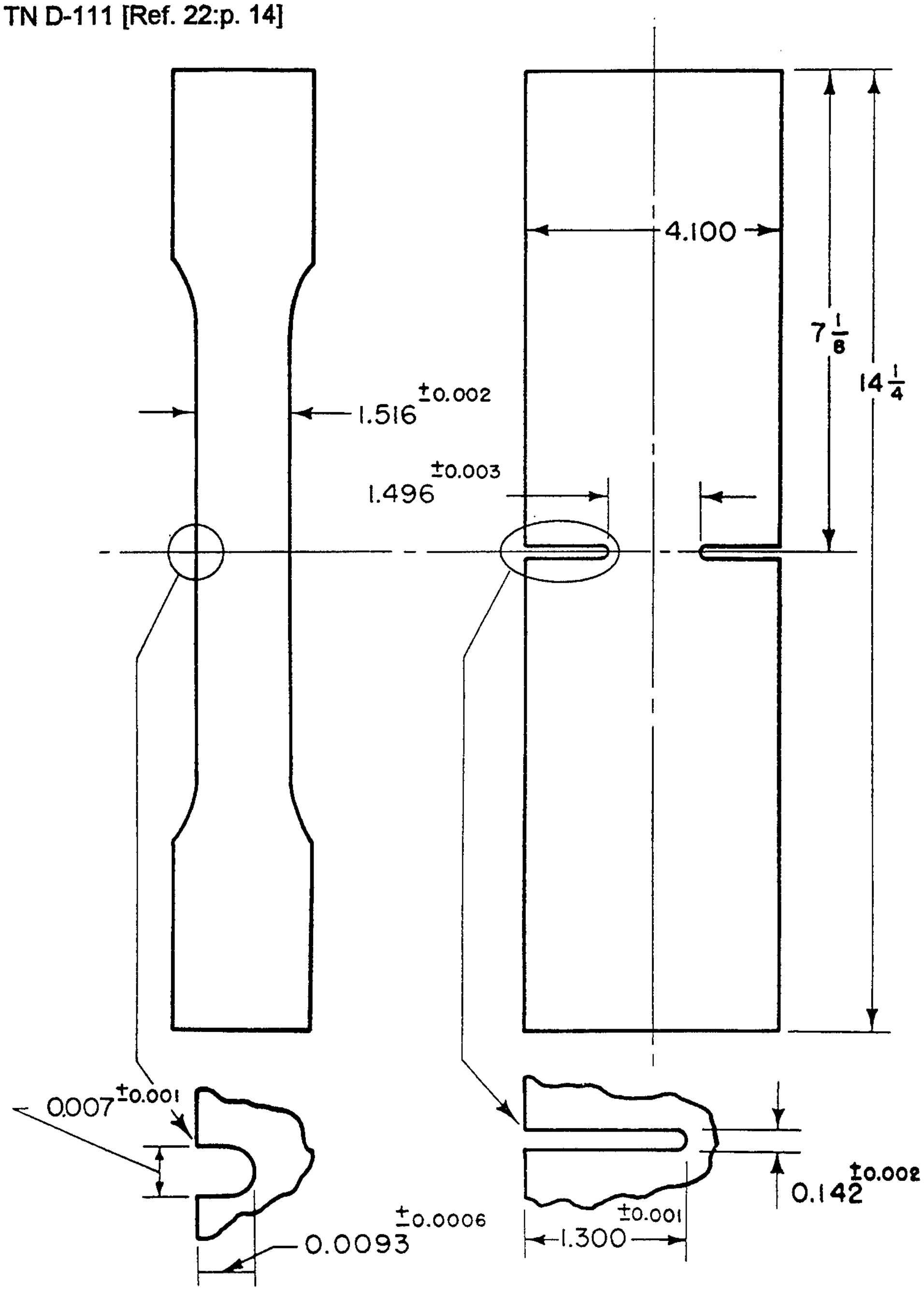


Material	Hole diameter, d, in.		
	W = 4 in. L = 20 in.	W = 2 in. L = 20 in.	W = $\frac{1}{2}$ in. L = 12 in.
7075-T6 aluminum alloy	1/8 1/4 2	1/16 1/8 1	1/32 1/8 1/4

Specimen configurations. All specimens were 0.091-inch thick

APPENDIX E. SPECIMEN DRAWINGS

NASA TN D-111 [Ref. 22:p. 14]

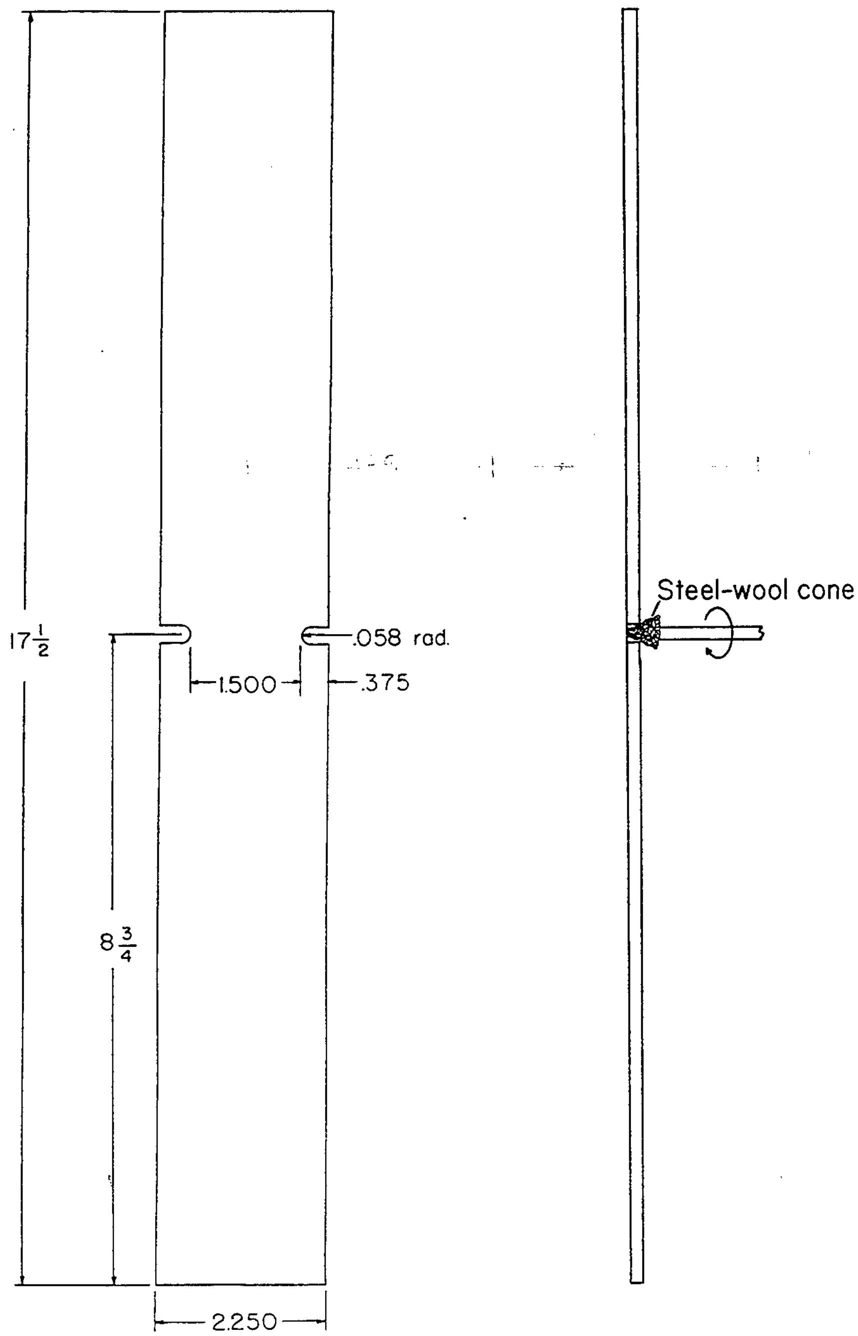


(a) Edge-notched specimen. (b) Notched specimen.

Notch details of notched and edge-notched fatigue test specimens. $K_t = 4.0$.

APPENDIX E. SPECIMEN DRAWINGS

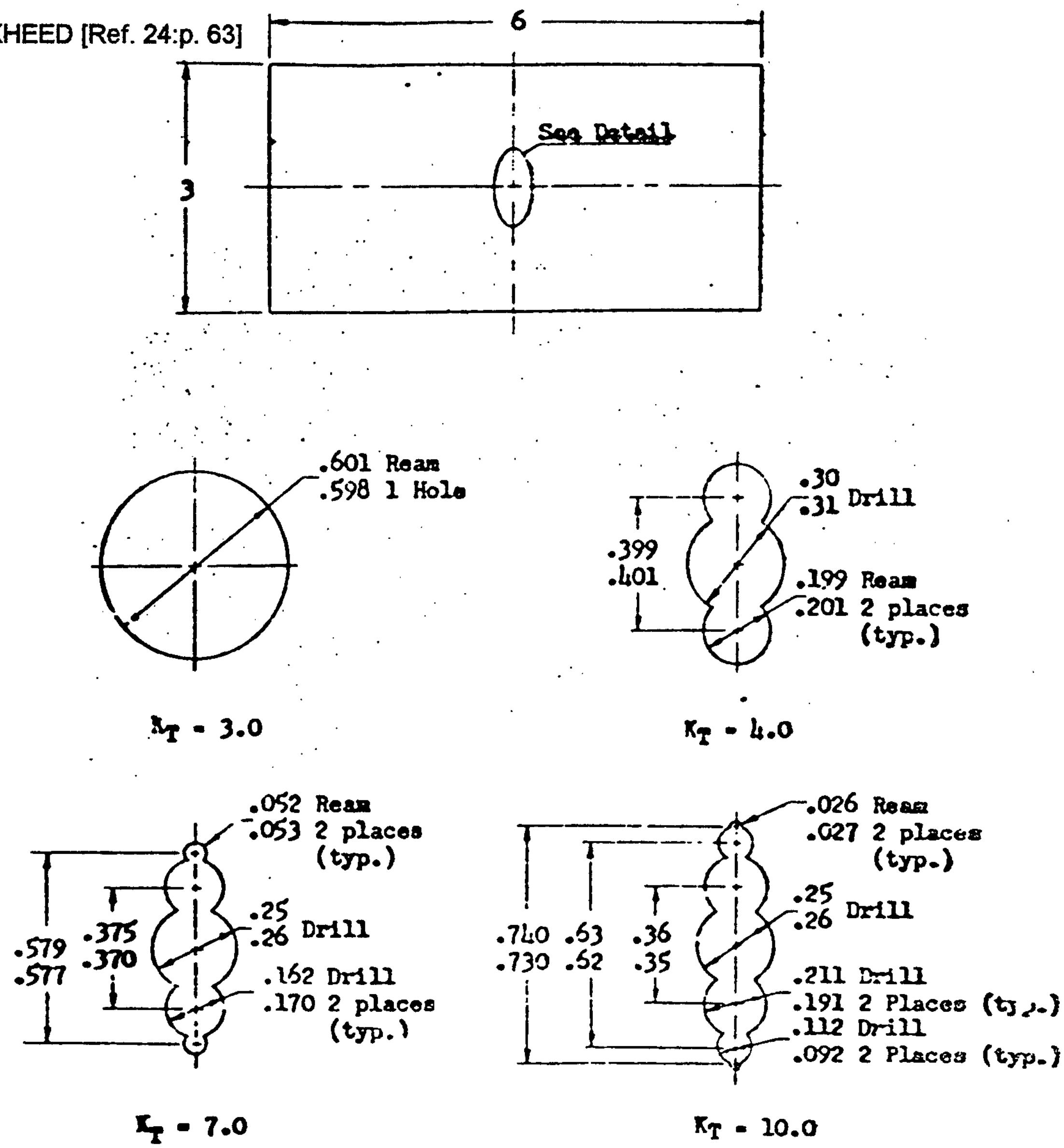
NASA TN D-212 [Ref. 23:p. 28]



(a) Specimen dimensions. (b) Deburring technique.

Sheet-specimen details.

LOCKHEED [Ref. 24:p. 63]

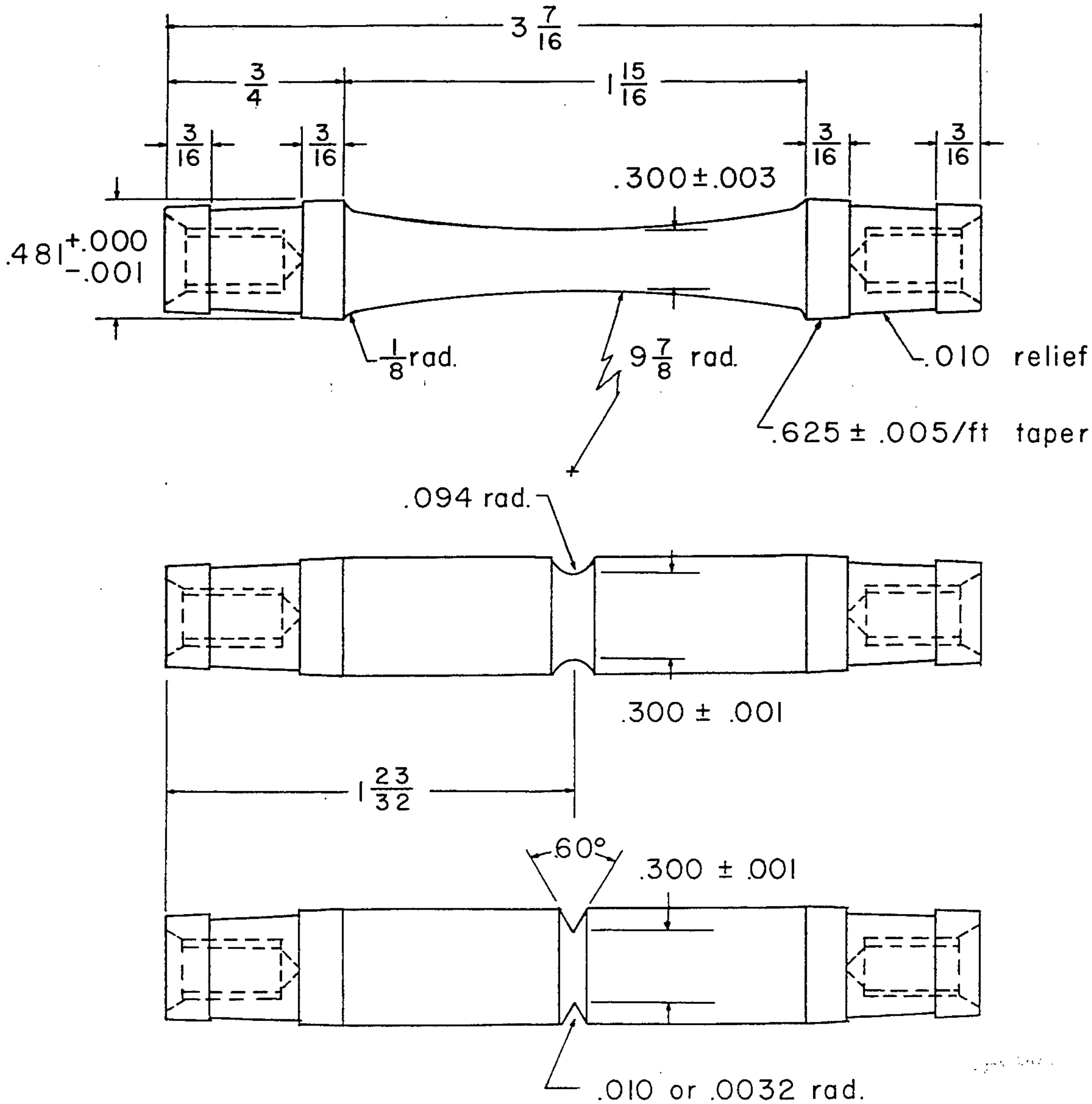


Note: All Dimensions Given In Inches

MATERIAL: 7075-T6 Bare Aluminum Alloy Sheet (.04 inches thick)
FABRICATION: Specimen Blanks Sheared to Size
Holes Drilled and Reamed
Burrs Removed by Light Stoning

Notched Sheet Test Coupons

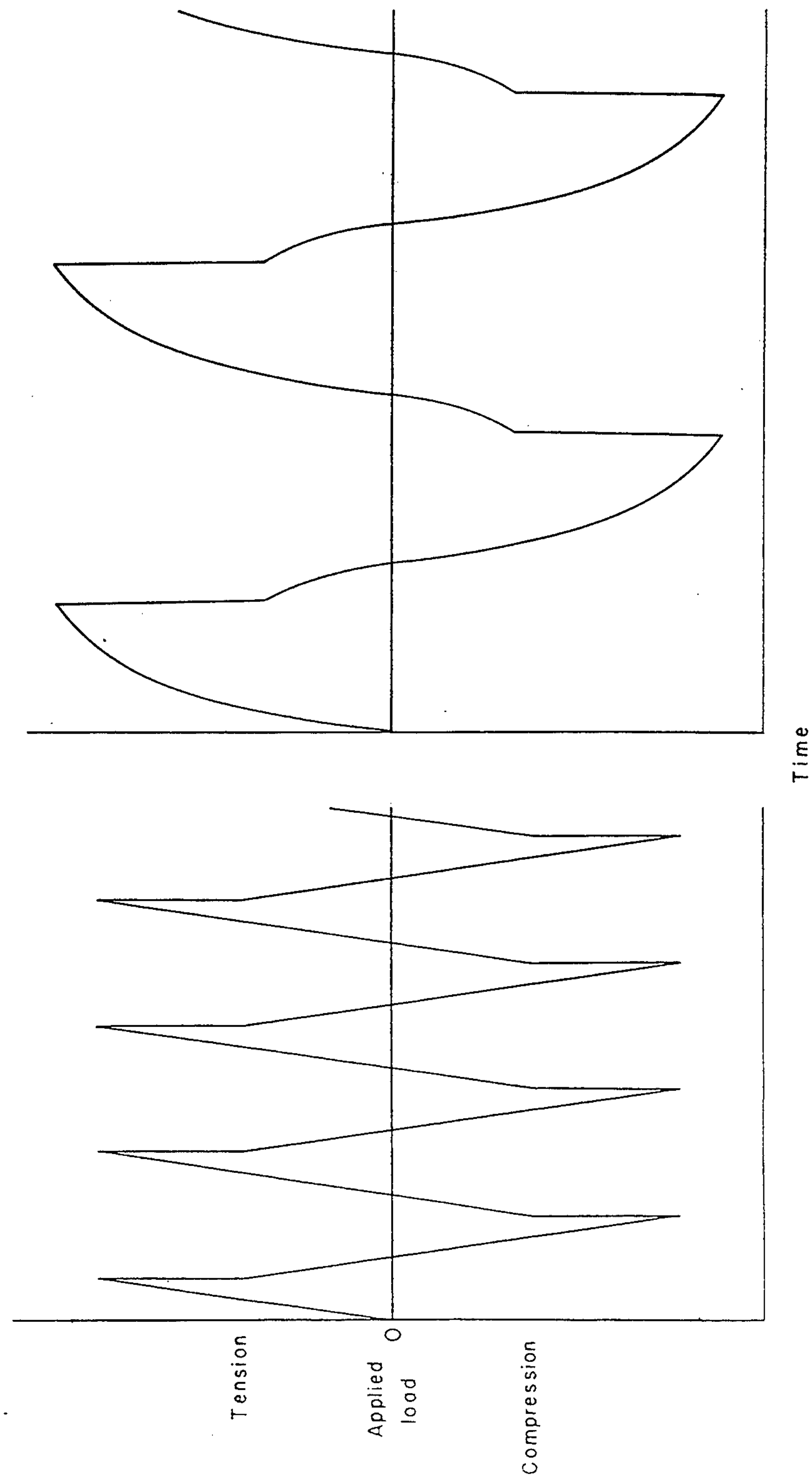
NASA TN D-210 [Ref. 25:p. 24]



Specimen configurations. All dimensions are in inches unless otherwise noted.

APPENDIX F. NACA "SAWTOOTH" LOAD SHAPES

NACA TN 3132 [Ref. 20:p. 11]



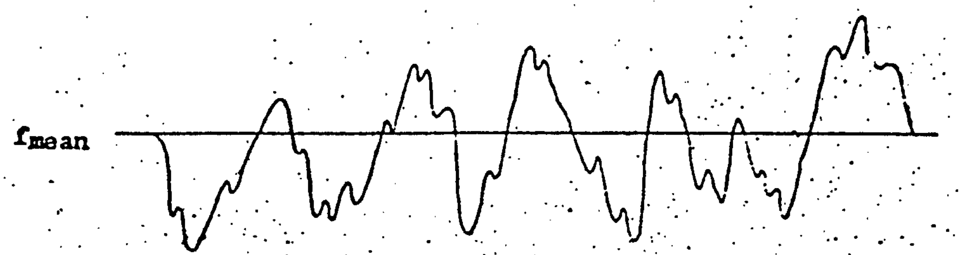
(a) Automatically controlled.

(b) Manually controlled.

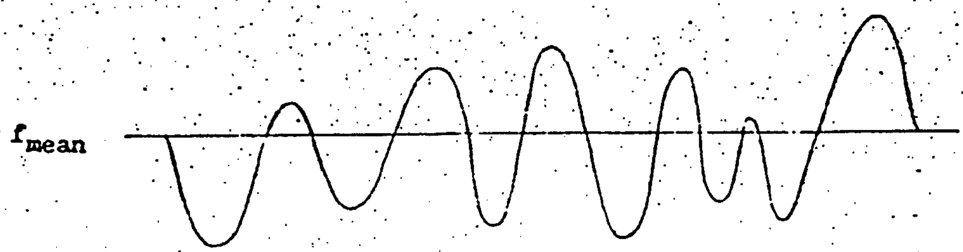
Typical load-time curves for double-acting hydraulic jack.

APPENDIX G. DEVELOPMENT OF GUST AND MANEUVER LOADING SPECTRA

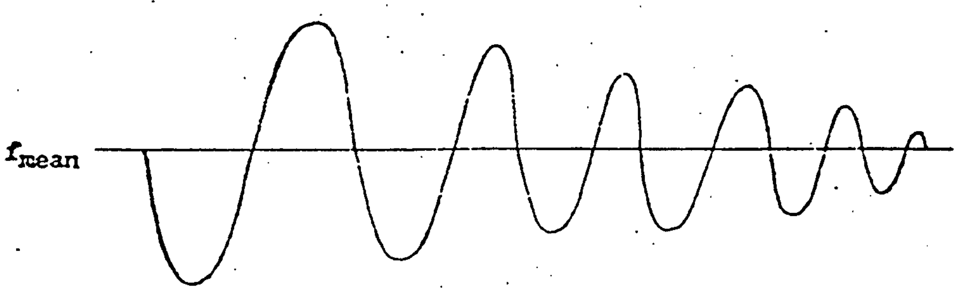
LOCKHEED [Ref. 24:p. 13]



Random Sequence of Flight Loads



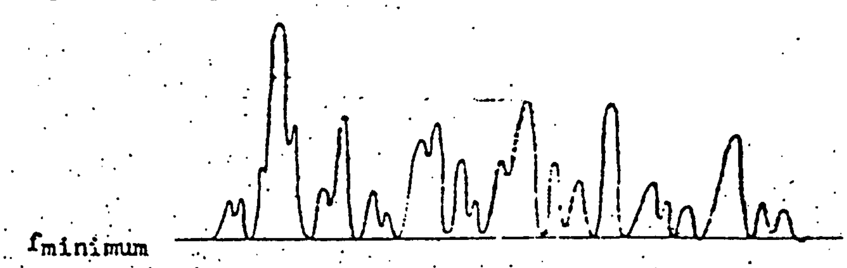
Random Grouping of Faired Flight Loads



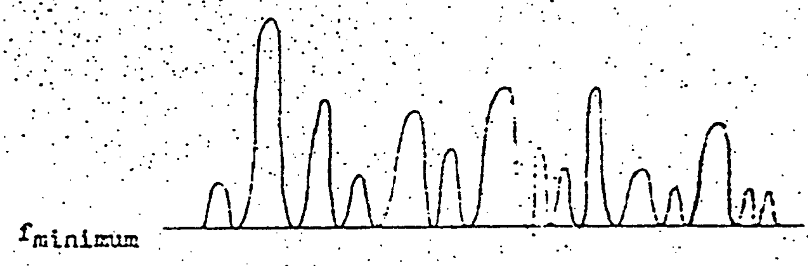
Ordered Grouping of Faired Flight Loads

Development of Gust Loading Spectra

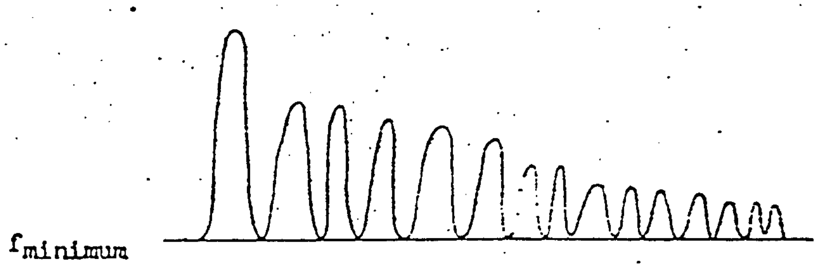
LOCKHEED [Ref. 24:p. 15]



Random Sequence of Flight Loads.



Random Grouping of Faired Flight Loads

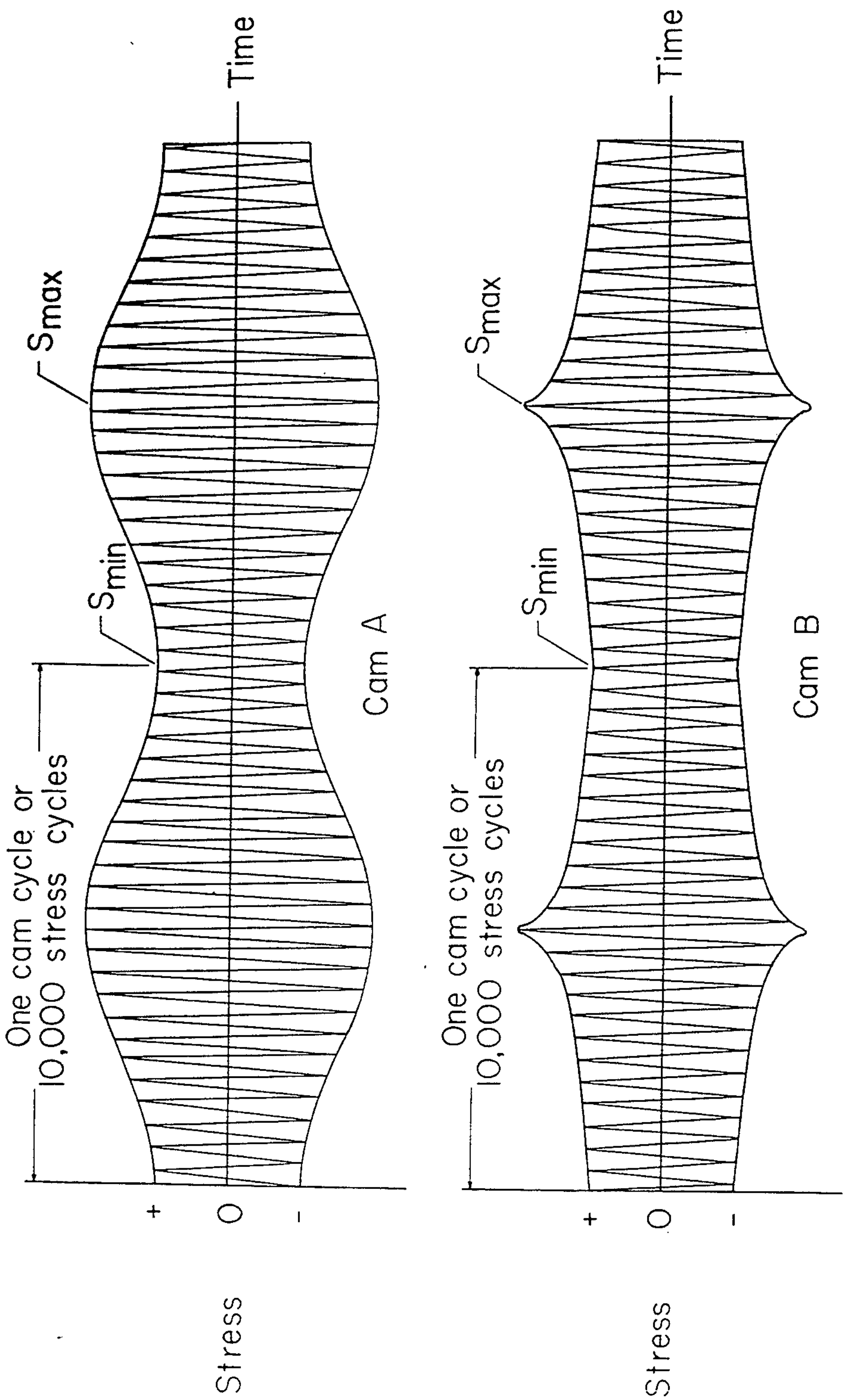


Ordered Grouping of Faired Flight Loads.

Development of Maneuver Loading Spectra

APPENDIX H. ROTATIONAL LOAD SHAPE SPECTRA

NASA TN D-210 [Ref. 25:p. 27]



Stress histories.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center 2
   8725 John J. Kingman Road., Ste 0944
   Ft. Belvoir, Virginia 22060-6218

2. Dudley Knox Library 2
   Naval Postgraduate School
   411 Dyer Rd.
   Monterey, California 93943-5101

3. Professor Edward M. Wu, Code AA/WU 2
   Naval Postgraduate School
   Monterey, California 93943-5106

4. Professor Gerald H. Lindsey, Code AA/LI 2
   Naval Postgraduate School
   Monterey, California 93943-5106

5. Department of Aeronautics and Astronautics, Code AA 1
   Naval Postgraduate School
   Monterey, California 93943-5106

6. CAPT J. J. Miller, Code 03 1
   Naval Postgraduate School
   Monterey, California 93943-5000

7. Commander 1
   Naval Air Systems Command (PMA-290FA/JP1)
   Attn: CDR Jeffrey Kunkel
   1421 Jefferson Davis Hwy.
   Arlington, Virginia 22243-2900

8. Commander 1
   Naval Air Systems Command (AIR-4.1.1.3/JP2)
   Attn: CDR J. B. Hollyer
   1421 Jefferson Davis Hwy.
   Arlington, Virginia 22243-5120

9. Commander 1
   Naval Air Systems Command (AIR-4.3.3.1/JP2)
   Attn: Mr. Nam D. Phan
   1421 Jefferson Davis Hwy.
   Arlington, Virginia 22243-5120

10. Patrol Squadron Special Projects Unit ONE 2
Naval Air Station Box 55
Attn: LT Todd R. Kousky
Hangar One
Brunswick, Maine 04011